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SYSTEMS ENGINEERING CAPSTONE PROJECT REPORT

DEVELOPING A WEBFIRES TRAINING SYSTEM

by

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June 2017

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ABSTRACT

This project report describes a proposed foundation for a system-of-systems training architecture that closes gaps in the Navy's current strike group training processes to more effectively train and support warfighters in the execution of a webfires concept. Today's fleet training systems lack the capability and capacity to provide adequate integrated training that leverages the necessary high-velocity learning expected of future warfighters who will employ and implement the webfires concept in the next 10 to 15 years. The current training processes and systems fail to provide sufficient hardware/software integration, training repetition, and performance feedback necessary to prepare warfighters to employ webfires against a near-peer threat.

This report details requirements that a future training system should possess to fill gaps in the Navy's current training process and align it with the Optimized Fleet Response Plan. It contains actionable recommendations for stakeholders and identifies key technology development areas that will enable a future webfires system. This report's recommendations will improve the way the Navy conducts fleet training and will create a competitive advantage in the maritime environment.

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LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---------------|--|
| AI | Artificial Intelligence |
| AR | Augmented Reality |
| AOR | Area of Responsibility |
| BFTT | Battle Force Tactical Trainer |
| C2 | Command and Control |
| C3 | Command, Control, and Communications |
| CIC | Combat Information Center |
| CNO | Chief of Naval Operations |
| COI | Critical Operational Issue |
| COMNAVSURFPAC | Commander, Naval Surface Forces, Pacific Fleet |
| COMPTUEX | Composite Training Unit Exercise |
| COMTHIRDFLT | Commander, Third Fleet |
| CONOPS | Concept of Operations |
| CONUS | Continental United States |
| CRUSER | Consortium for Robotics and Unmanned Systems Education and Research |
| CSG | Carrier Strike Group |
| DH | Department Head |
| DOD | Department of Defense |
| DoDAF | Department of Defense Architecture Framework |
| DSL | Digital Subscriber Line |
| DSTA | Defense Science and Technology Agency |
| ESG | Expeditionary Strike Group |

| | |
|---------|---|
| EWTG | Expeditionary Warfare Training Group |
| FOUO | For Official Use Only |
| FST | Fleet Synthetic Trainer |
| GSEAS | Graduate School of Engineering and Applied Sciences |
| HF | High Frequency |
| IA | Information Assurance |
| IFS | Introductory Flight Screening |
| INCOSE | International Council on Systems Engineering |
| IRB | Institutional Review Board |
| JSAF | Joint Semi-Automated Forces |
| KPP | Key Performance Parameter |
| LAN | Local Area Network |
| LHA/D | Landing Helicopter Assault/Dock Vessel |
| LOE | Line of Effort |
| LOS | Line-of-Sight |
| LVC | Live, Virtual, and Constructive |
| MOE | Measure of Effectiveness |
| MOP | Measure of Performance |
| MSC | Military Sealift Command |
| MTWS | Marine Air-Ground Task Force Tactical Warfare Simulation |
| NAS | Naval Air Station |
| NAWDC | Naval Aviation Warfighting Development Center |
| NEC | Navy Enlisted Classification |
| NIFC-CA | Naval Integrated Fire Control-Counter Air |

| | |
|-----------|---|
| NIFC-CU | Naval Integrated Fire Control-Counter Undersea |
| NPS | Naval Postgraduate School |
| NSWDC | Naval Surface Warfighting Development Center |
| NTSP | Navy Training Systems Plan |
| NWDC | Naval Warfare Development Center |
| OA | Operational Activity |
| OFRP | Optimized Fleet Response Plan |
| OMOE | Overall Measure of Effectiveness |
| OPNAV | Office of the Chief of Naval Operations |
| OPNAV N9 | Deputy Chief of Naval Operations for Warfare Systems |
| OPNAV N9I | Deputy Chief of Naval Operations for Warfare Systems Integration |
| OTH | Over-the-Horizon |
| PBED | Plan, Brief, Execute, Debrief |
| RSAF | Republic of Singapore Air Force |
| SEA | Systems Engineering Analysis |
| SME | Subject Matter Expert |
| SMWDC | Naval Surface and Mine Warfighting Development Center |
| SNA | Student Naval Aviator |
| SWO | Surface Warfare Officer |
| TDSI | Temasek Defense Systems Institute |
| TRE | Tactical Readiness Examination |
| TTG/L/P | Tactical Training Group, Atlantic/Pacific |
| TTP | Tactics, Techniques, and Procedures |
| TYCOM | Type Commander |

| | |
|------|--------------------------------|
| UHF | Ultra-High Frequency |
| USFF | United States Fleet Forces |
| USMC | United States Marine Corps |
| USN | United States Navy |
| USV | Unmanned Surface Vehicle |
| VHF | Very-High Frequency |
| VR | Virtual Reality |
| WDC | Warfare Development Center |
| WFTS | Webfires Training System |
| WIC | Warfare Innovation Continuum |
| WTI | Weapons and Tactics Instructor |

EXECUTIVE SUMMARY

The nature of naval warfare is continuously evolving. The traditional kill chain approach is expected to be insufficient to neutralize near-peer threats in the future. To increase the combat effectiveness of the U.S. Navy in a future combat environment, the Navy is shifting its warfighting approach to a kill web, or webfires, concept of operations. In his 2016 interview with the U.S. Naval Institute, Admiral Manazir postures that unlike the current kill chain process in which units are limited to engagements utilizing organic sensor data, future units will instead be able to work together to “create a cross-domain kill web” able to share combat-relevant data for the purpose of tracking and engaging an adversary. This shift in the way the Navy fights calls for a new approach to training the Navy’s future warfighter. This report details a systems engineering approach for developing a webfires training system (WFTS) to prepare the future warfighter for an engagement with a near-peer threat.

A. SCOPE AND ASSUMPTIONS

Due to time constraints and still-maturing Webfires concepts, the team applied some significant assumptions and boundaries to scope the problem to a manageable level. These assumptions allowed the team to focus their efforts into determining capability gaps in the Navy’s current training system, generating a base list of requirements for the future WFTS to meet, identifying key software/hardware capabilities, selecting the main organizations that will support training and their tasks, and research technology that will support these functions and organizations. Completion of these tasks allowed the team to build a foundation upon which a full system architecture can be built in the future.

B. CAPABILITY GAPS

Stakeholder Analysis identified four key capability gaps: the absence of any webfires concept training today, a lack of multi-unit training repetition to support high-velocity learning, a lack of compatible networks to support integration of units and simulators for webfires training, and a lack a quality feedback to facilitate high-velocity learning.

The Navy is currently developing the webfires concept. The recent deployment of the first capable Naval Integrated Fire Control – Counter Air (NIFC-CA) strike group demonstrates that such a concept is being developed and implemented by the fleet. The implementation of NIFC-CA is just one small aspect of the webfires concept. If all Carrier Strike Group or Expeditionary Strike Group (CSG/ESG) units are able to share fire control data with each other, then the webfires concept can be implemented across the air, surface, and undersea warfare domains, which is consistent with Admiral Manazir’s vision for networked warfare as discussed with the U.S. Naval Institute in September 2016. For warfighters to implement this advanced weapons system effectively, they require doctrine. This capstone report recommends that the Naval Warfare Development Center (NWDC) coordinate with the other warfare development centers to document a unified set of tactics, techniques, and procedures (TTPs) that are used by all warfighters to implement and train for webfires.

Additionally, the network capability of today’s training system is not robust enough to support the repetition necessary to facilitate high-velocity learning and in turn results in less efficient multi-unit training. Currently, the only complete CSG/ESG multi-unit training is performed during Composite Training Unit Exercises (COMPTUEX) within the integrated phase of the Optimized Fleet Response Plan (OFRP) to certify a CSG or ESG for deployment and entry into the sustainment phase of the OFRP. Currently, the Tactical Training Groups (TTG) have the ability to facilitate fleet synthetic training (FST) events prior to COMPTUEX. However, due to the nature of the training network and the reliance on large numbers of people to conduct these FST events, the TTGs can only perform one simulation at a time. A more robust, decentralized training network along with a database of preprogrammed training simulations will greatly increase the potential for more frequent integrated training.

Lastly, repetition is only one aspect of high-velocity learning. For high-velocity learning to work, training must be current, accurate, and relevant. This report recommends that the future WFTS collect and produce data that is used by the NWDC to assess the current engagement doctrine. By incorporating a feedback loop into the training system, the doctrine can be updated to reflect better approaches to attack an

enemy during the training process, and correct deficiencies discovered in the doctrine. Additionally, the collected data may be used by the appropriate teams in certifying and evaluating units for deployment. This could potentially reduce training and certification requirements. However, for this feedback loop to work, the NWDC, along with the certification and evaluation teams, must establish well-defined data collection requirements.

C. REQUIREMENTS

Based on the identified Capability Gaps, the team developed the following capability requirements for the WFTS:

1. Webfires Concept Training Requirements
 - a. Fit into the basic, integrated, and sustainment phases of the OFRP
 - b. Integrate training during both unit and multi-unit training
 - c. Integrate training during in-port and at-sea
2. Repetition Requirements
 - a. Provide standardized training scenarios for unit and multi-unit training
 - b. Provide training capability in a limited communication environment
 - c. Capable of allowing units and simulators to independently establish their own training networks for simulation.
 - d. Shall integrate with future strike group units' networks, training facilities, and simulators
3. Feedback Requirements
 - a. Provide data that can be used to assess doctrine against a near-peer threat
 - b. Provide data that can be used to aid certification and evaluation of units during the OFRP.

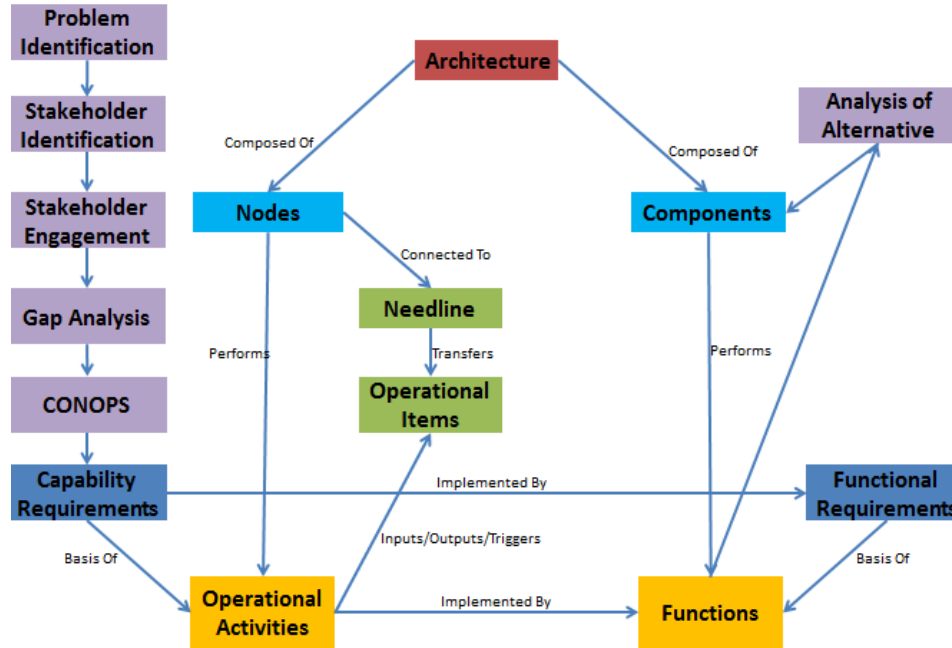
D. FUNCTIONAL ANALYSIS

The functional analysis identified key functions that the future training system must meet in order to satisfy capability requirements and fill capability gaps. The functional analysis looked at both hardware/software function and organization functions/responsibilities that are performed. Most notably, this report identifies the key organizations that will be involved in this future training system and their tasks. Those organizations are the Intelligence Community, NWDC, TTGs, Numbered Fleets, CSG-4/15, Operational Strike Group Commanders, CSG/ESG Units, and their embedded simulators. These organizations must jointly produce effective webfires training objectives to create future simulations that will aid CSG/ESG unit training to a near-peer threat level. Additionally, these organizations must establish effective data requirements that the WFTS must meet in order to aid certification and evaluation and allow the NWDC to assess webfires doctrine and update it accordingly.

E. SYSTEM ARCHITECTURE

This report develops a foundation upon which a more in-depth system architecture can be produced once webfires systems components are online. The most significant aspect of this foundation is the identification of the Nodes, Operational Activities, Functions, and enabling Components. Figure 1 shows the process used to design and create this foundation.

- Nodes are the organizations that are involved in this training system.
- Operational activities are the tasks that the organizations have to perform in order to support training, increase repetition, and provide high-velocity learning.
- Functions support and enable the operational activities.
- Functions are performed by components.



Adapted from CORE Architecture Definition Guide (DoDAF v2.02)

Figure 1. WFTS Foundational Architecture Flow

F. WFTS RECOMMENDED TECHNOLOGIES

Since the webfires concept is still in its infancy, this project focuses on general technological capabilities that the WFTS components must possess to facilitate repetition, high-velocity learning, and performance feedback. Using an analysis of alternatives approach, this report identifies the technologies that would be most useful in comprising the WFTS. These significant technologies are:

- Artificial intelligence systems or automated systems to play red forces during simulations.
- An advanced mesh network topology.

Current multi-unit simulations conducted by the Navy are people-intensive. Simulations require a large number of personnel to play the red force. This in turn limits the number and the frequency of quality simulations that are performed at any given time. By augmenting simulations with a red force played by some sort of artificial intelligence or automated responses, the quality and quantity of training can be increased.

The current training network is essentially comprised of a star network topology with the TTGs acting as the central node to coordinate and connect units and simulators to the training network. To increase training repetition and high-velocity learning for units in port and at sea along with the incorporation of land-based simulators, a more decentralized network topology is needed. The difficulty of implementing a mesh training network is compounded by information assurance issues, lack of sufficient network connections, and lack of sufficient training network interfaces to stimulate combat systems on ships.

G. ANALYSIS OF ALTERNATIVES

A morphological box is used in this study to develop nine design alternatives. These nine design alternatives were developed to showcase nine different aspects the WFTS should be capable of performing. Qualitative comparisons are used to rank each of the nine alternatives. These alternatives helped the team determine which aspects of the WFTS may provide the biggest benefits for a training system focused on high-velocity learning. The analysis and alternatives section in the report discusses each of the nine alternatives and the results of all comparisons. The intent in comparing alternatives was not to limit selection to one finalized recommended design, but rather to highlight additional possibilities regarding capabilities and limitations to use for further research and development of the WFTS.

H. ITEMS FOR FURTHER RESEARCH

Through research and stakeholder interviews, the authors discovered multiple relevant topics with respect to training, webfires, and webfires training. Due to time constraints and project scope, the team was unable to explore many of these extremely relevant topics. However, these topics are important for implementing webfires, advancing the implementation of a WFTS, and improving warfighter training in general. This report recommends that further research on the following topics would be in the best interest of the Navy:

- Communication network advancement.
- Artificial intelligence and machine learning.
- Navy Training Systems Plan for the WFTS.
- Technology to augment face-to-face briefing and debriefing.
- Information assurance.
- The importance and incorporation of more SMEs in the training process.

I. CONCLUSIONS

The key to providing high-velocity learning is increasing repetition, providing effective feedback, and providing quality training. The future WFTS will provide high-velocity learning by incorporating rapid data feedback, simulations, and increased connectivity.

- Clear data collection, processing, and distribution requirements must be established
- Investment into being able to provide simulations using real warfighting equipment must be made to increase the quality of training
- Information Assurance requirements, network topology, and communications bandwidth limitations must be addressed to allow more repetition and repeatability

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ACKNOWLEDGMENTS

The team would like to acknowledge the incredible amount of time and effort put forth by our faculty advisors, including Mr. Bill Hatch, Graduate School of Business and Public Policy, academic associate, Manpower Systems Analysis; and Associate Professor Dr. Fotis Papoulias, CDR, USN (Retired), Department of Systems Engineering. Without their attendance at team meetings and occasional course corrections, none of this would have been possible. An additional thanks is due to our third advisor, Dr. Michael Atkinson, Department of Operations Research.

The professionals who teach within the Systems Engineering and Operations Research Departments make up the core of systems engineering analysis instruction. The concerted effort of the professors and support from the staff provided the knowledge and know-how to complete this project. We would like to specifically identify the following personnel for their direction and support:

- Chuck Good, CAPT, USN
- Jeffrey Kline, CAPT, USN (Retired)
- Greg Miller, CDR, USN (Retired)
- Mark Stevens, LTC, USA (Retired)
- Vince Naccarato, LCDR, USN

Stakeholders' input on the current and future state of operations within the U.S. Navy provided a solid foundation for this project. We especially thank the following commands for dedicating time and effort:

- Expeditionary Warfare Training Group, Pacific (EWTGP)
- Naval Aviation Warfighting Development Center (NAWDC)
- Naval Surface and Mine Warfighting Development Center (SMWDC)
- Naval Surface Force, U.S. Pacific Fleet (COMNAVSURFPAC)
- Tactical Training Group, Pacific (TTGP)
- U.S. Third Fleet (COMTHIRDFLEET)

Accomplishing this capstone would not have been possible without the love and support of our families during the previous two years of late nights, meetings, and classes that were required to complete the systems engineering analysis program. Thank you and we love you.

Finally, the team would like to dedicate this body of work to our friend and classmate, Michael Castillo.

I. INTRODUCTION

The United States Navy (USN) has been the cornerstone of the nation’s power projection and security for over 240 years. To sustain such an obligation under an ever-changing and dynamic environment, the Navy must develop the concepts and capabilities to provide our national leaders with options for handling situations ranging from non-conflict stability operations to near-peer combat at sea.

Current combat systems are often closely linked among the various forces of a strike group. The concept of integrating unmanned systems into distributed lethality and the ability to communicate among distant forces to provide overwhelming offensive firepower against an adversary was evaluated in a previous systems engineering analysis capstone report (Erstad et al. 2016). The distributed lethality construct rapidly expanded into the proposed webfires concept, which integrates the air, surface, and sub-surface domains in a highly-connected network to achieve unparalleled communication and fire-support abilities among the various elements of a strike group. Systems Engineering Analysis Cohort 25, collectively referred to as “the team” for the remainder of the report, was tasked to develop a training architecture to enable the adoption of the previously described webfires concept. This architecture will leverage the potential technologies of the 2025 to 2030 timeframe and use the principles of high-velocity learning as the foundation of the training system.

A. ORGANIZATION OF THE REPORT

The entire project is documented in 12 chapters. These chapters are organized in a way that mirrors the process the team followed to create the training system architecture. The team began by examining several systems engineering process models, which are described in a later section of this chapter, and chose an appropriate systems design approach. The report follows the team’s efforts to understand the problem, identify and analyze gaps, generate system architectures, and ultimately recommend a comprehensive design that is not only appropriate to the tasking, but also satisfies the stakeholders’ needs.

The first three chapters provide for the framework and context of the problem. Chapter I, “Introduction,” provides an overview of the project, including project background, project team, the foundations on which the project is built, systems engineering process models, and system design approach. Chapter II, “Problem Definition,” provides an analysis of the true nature of the tasking statement and the problem statement that the team derived from it. This chapter also defines terminology essential to the understanding of this system architecture as well as the assumptions and boundaries to the problem that are critical to framing the proposed training system within the context of the larger webfires concept. Chapter III, “Needs Analysis,” summarizes the process to discover the needs of the stakeholders and the specific issues that were raised through research, stakeholder site-visits, and interviews.

The next three chapters analyze the current training system and how integration plays a part, as well as analyzing and comparing the current system to the needs of the proposed webfires training system (WFTS). The third chapter in this section provides an overview of the purpose and methodology of the future training system. Chapter IV, “Current Training Process,” details the methods and process that current naval personnel undergo to achieve individual qualifications as well as unit level qualifications. Chapter V, “Gap Analysis,” compares the current process to the defined needs of the future system as discovered through stakeholder interviews. This analysis presents several major gaps that the proposed system architecture will attempt to resolve. Chapter VI, “Concept of Operation,” details the general process that personnel and units will undergo in the proposed WFTS.

Chapters VII through X capitalize on the identification of gaps and the problem definition to lay out a system-of-systems design. Chapter VII, “System Requirements,” looks at both the capabilities and requirements that a system must possess in order to fill the gaps that are determined in Chapter V. Chapter VIII, “Functional Analysis,” identifies the system functions, both people and material, that the system must have to meet the requirements identified in Chapter VII.

Chapter IX, “Analysis of Alternatives,” presents the process that the team used to complete an analysis of alternatives. This analysis enabled the team to identify which

design option best addresses the gaps identified in Chapter V. Chapter X, “System Architecture,” combines all of the efforts of the previous chapters and formulates a comprehensive system architecture.

Finally, this report concludes with a Chapter XI, “Summary, Conclusions, and Recommendations.” The final chapter summarizes this report’s findings, contains a detailed list of conclusions along with actionable recommendations, and a list of recommended topics for further research. The various appendices at the end of the report contain the official tasking statement, amplifying information for certain chapters, and Institutional Review Board (IRB) approved questions and documentation.

B. PROJECT BACKGROUND

The capstone project officially started in September 2016 during the fall 2017 academic quarter. The team was required to identify and integrate students from the National University of Singapore’s Temasek Defense Systems Institute (TDSI), as well as students and faculty of relevant Naval Postgraduate School (NPS) programs into the project to provide technical knowledge and insights and aid in research and report writing. The team then had three quarters to deliver a completed project report and final briefing materials to NPS faculty advisors and the Pentagon. The team received official tasking from the Office of the Chief of Naval Operations (OPNAV) Deputy Chief of Naval Operations for Warfare Systems – Integration Division (N9I).

C. PROJECT TEAM

NPS enrolls and educates a diverse set of military officers from around the world in several graduate schools and degree programs. The Systems Engineering Analysis (SEA) team comes from an interdisciplinary program from both the Graduate School of Engineering and Applied Sciences (GSEAS) and the Graduate School of Operational and Information Science (GSOIS). The resident students critical to the success of this project, as well as their warfare backgrounds, are listed in Table 1.

Table 1. Resident Team Members

| <u>Rank and Name</u> | <u>Service</u> | <u>Warfare Designator and Past Experience</u> |
|-----------------------------|-----------------------|--|
| LCDR Daniel DeCicco | USN | Naval Aviator, MH-60S |
| LT Matthew Alvarez | USN | Naval Aviator, MH-60S/SH-60F/HH-60H |
| LT Benjamin Arnett | USN | Naval Aviator, MH-60S |
| LT Michael Hook | USN | Surface Warfare Officer, CRU/DES |
| LT Austin Thompson | USN | Submarine Warfare Officer, SSBN |
| LT Kevin Weeks | USN | Surface Warfare Officer, CRU/DES |
| LT Seng Yee | USN | Information Professional Officer, CRU/DES |

Supplementing the core team are students that have completed at least six months of graduate education at Singapore's TDSI. These students are required to contribute to this project in partial fulfillment of their own degree requirements. Additionally, these individuals bring a wide variety of knowledge and experience to the table, even as they are working in their own academic disciplines and completing individual theses. Their specialties are in the areas of operational research, computer science, mechanical, electrical, and weapon systems engineering, oceanography, and physics. These specialists and their backgrounds are listed in Table 2.

Table 2. TDSI Cohort Members

| <u>Rank & Name</u> | <u>Service</u> | <u>Background and Course of Study</u> |
|-------------------------------|---------------------------|---|
| LT Ryan Beall | USN | Naval Aviator, MH-60S (Systems Engineering) |
| LT Preston Tilus | USN | Surface Warfare Officer, CRU/DES (Operational Research) |
| LTJG Clayton Petty | USN | ADM Frank Bowman Scholarship (Mechanical Engineering) |
| MAJ Dor Kronzilber | IDF | Army Officer (Operational Research) |
| ME5 Ang Chin Beng | RSAF | Air Force Engineer (Weapon Systems Engineering) |
| ME5 Kang Wei Sheng | SA | Army Engineer (Systems Engineering) |
| ME5 Ang Pak Siang | RSAF | Air Force Engineer (Communications Engineering) |
| CPT Ang Wee Kiong | SA | Army Intelligence Officer (Systems Engineering) |
| MAJ Hoon Dingyao | SA | Signals Officer (Computer Science) |
| CPT Gay Wee Choon | SA | Armor Officer (Operational Research) |
| MAJ Soh Yuan Wei | SA | Combat Engineer Officer (Systems Engineering) |
| Yee Jian Hong | DSTA | Advanced System (Weapon Systems Engineering) |
| Ang Cheng Hai | DSTA | Air System (Communications and Network Engineering) |
| Han Keng Siew | DSTA | Network Systems (Systems Engineering) |
| Foo Yueng Hao | DSTA | Communications Infrastructure (Computer Science) |
| Chin Hon Keong | Civilian Defense Industry | Land Systems (Weapon Systems Engineering) |
| See Hongze | | Marine Systems (Systems Engineering) |
| Toh Ying Jie | | Electrical and Electronic Systems (Systems Engineering) |
| Lai Wee Leong | | Electrical and Electronic Systems (Systems Engineering) |
| Tan Choon Seng | | Aerospace Systems (Weapon Systems Engineering) |

The team has been supported by many faculty members through mentorship and instruction during their graduate education. Without the support, superior knowledge, and practical experience of the lecturers and faculty advisors, the team would not be able to focus their work into a meaningful discussion in the form of this report. The faculty

advisors and subject matter experts (SMEs) especially critical to the success of this project, as well as their respective departments, are listed in Table 3.

Table 3. Resident Faculty Advisors

| <u>Rank and Name</u> | <u>Role</u> | <u>Experience</u> |
|--------------------------------|--------------------|--|
| Dr. Fotis Papoulias | Advisor | NPS Associate Professor, Systems Engineering |
| Dr. Michael Atkinson | Advisor | NPS Professor, Operational Research |
| CDR (Ret.) Bill Hatch, USN | Advisor | NPS Professor, Manpower Systems Analysis |
| CAPT (Ret.) Jeffrey Kline, USN | SEA Chair | NPS Professor of Practice, Operations Research |
| CAPT Chuck Good, USN | SME | COMNAVSURFPAC Detachment, Monterey |

D. PROJECT FOUNDATIONS

The recommendations within this report are based on the foundations of the Chief of Naval Operations' (CNO) vision statement titled *A Design for Maritime Superiority*. Contained within are various lines-of-effort (LOE) that contribute to this vision and some principles that enable them (Richardson 2016). Innovation and critical thinking play heavily into the Admiral Richardson's vision (2016), and accordingly, the capstone process began in earnest with participation in the annual Warfare Innovation Continuum (WIC) Workshop sponsored by the Consortium for Robotics and Unmanned Systems Education and Research (CRUSER), held each fall at NPS.

1. The CNO's Design for Maritime Superiority

The CNO's 2016 vision contains several critical LOEs that provide a backdrop for the implementation of the WFTS. The maritime superiority design concept, in addition to the proposed webfires concept, draws a focus on fleet-wide readiness to engage in a naval battle in all waters and air spaces. According to the CNO (2016), the primary concepts for implementation focus on the following six pinnacles:

1. Maintain and modernize the undersea leg of the strategic deterrent triad. This is foundational to our survival as a nation.
2. In partnership with the Marine Corps, develop concepts and capabilities to provide more options to national leaders, from non-conflict competition to high-end combat at sea. Operations short of conflict should be designed to contain and control escalation on terms favorable to the U.S. Combat at sea must address “blue-water” scenarios far from land and power projection ashore in a highly “informationalized” and contested environment. All scenarios must address the threat of long-range precision strike. Test and refine concepts through focused wargaming, modeling, and simulations. Validate these concepts through fleet exercises, unit training, and certification.
3. Further advance and ingrain information warfare. Expand the Electromagnetic Maneuver Warfare concept to encompass all of information warfare, to include space and cyberspace.
4. To better meet today’s force demands, explore alternative fleet designs, including kinetic and non-kinetic payloads and both manned and unmanned systems. This effort will include exploring new naval platforms and formations—again in a highly “informationalized” environment—to meet combatant commander needs.
5. Examine the organization of United States Fleet Forces Command, Commander Pacific Fleet, and their subordinate commands to better support clearly defining operational and warfighting demands and then to generate ready forces to meet those demands.
6. Examine OPNAV organization to rationalize our headquarters in support of warfighting requirements. Warfare Innovation Continuum. (Richardson 2016, 6)

Also critical to the success of the WFTS is the introduction and use of high-velocity learning. This is a primary tenet of the CNO’s vision. In the *NPS Update* newsletter dated August 2016, Kenneth A. Stewart summarizes the origin of high-velocity learning:

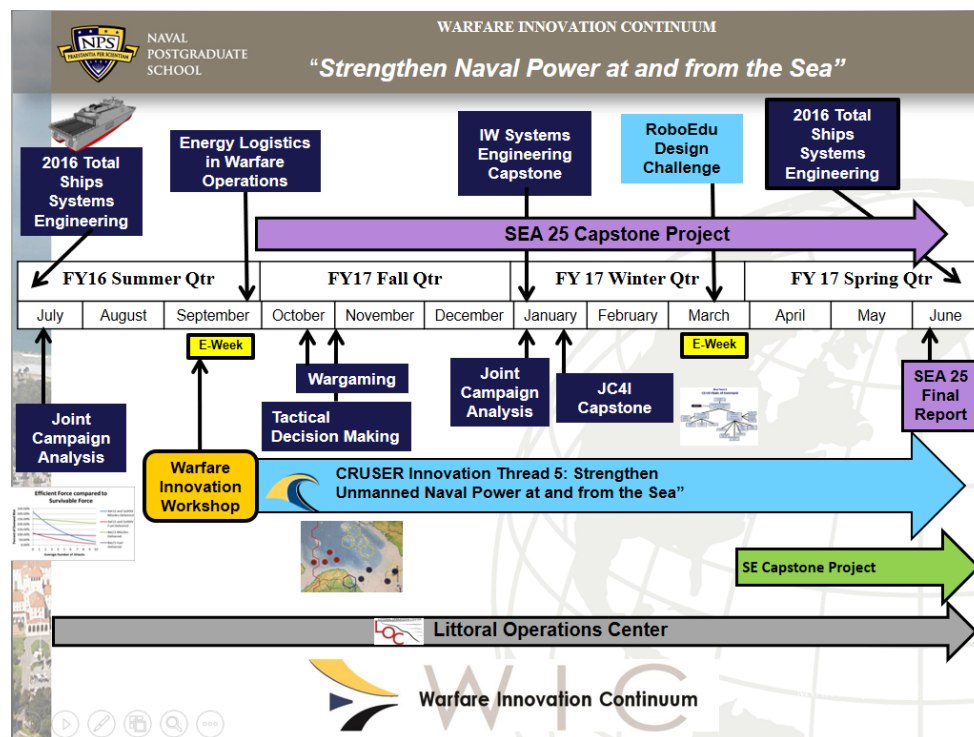
The term high-velocity learning was penned by Steven J. Spear in his book, *The Velocity Edge*. This innovative model explores methods for building a system of “dynamic discovery” for seeing and solving problems as they occur, sharing information to help convert weaknesses into strengths, and developing leaders who are invested in their subordinates’ successes. (Stewart 2016, 3)

It is important to note that high-velocity learning is a skill and, like any other skill, it requires practice.

2. Warfare Innovation Continuum Workshop

The annual WIC workshop is a themed and coordinated effort to leverage NPS cross-campus educational and research activities as well as technology and defense industry personnel to explore innovative solutions and “apply emerging technologies to shape the way we fight” (CRUSER 2016). The main thrusts of the CNO’s vision, as well as how the foundations of systems engineering will contribute to its success, are expanded upon in the following paragraphs.

The timeline for the annual WIC is displayed in Figure 1, where the important capstone deadlines are annotated in addition to some coursework and academic milestones. As the graphic shows, the WIC Workshop was held in September 2016, and the capstone report is due in June 2017.



Source: CRUSER (2016).

Figure 1. 2016 WIC Timeline and Project Milestones.

In the fall of 2016, a continuum focused on naval power in the littorals and titled *Developing Autonomy to Strengthen Naval Power* was held at NPS (CRUSER 2016). The purpose of this conference was to integrate members from a variety of backgrounds to apply creative-thinking skills and propose unique solutions to a theoretical future combat problem. The diverse personnel in attendance included warfare-qualified U.S. military officers and civilians enrolled in various degree programs at NPS, engineers from Silicon Valley and Department of Defense (DOD) laboratories, and accomplished members of the academic community.

a. WIC Workshop Focus Areas

As found on the WIC Sakai website, this group of diverse professionals concentrated their incorporation of ideas and technologies into three main discussion areas:

1. Littoral Mesh Networking and Remote Sensing: These concepts all employ autonomy to create a mesh network of communications and sensing nodes in a contested urban littoral environment. Concepts in this category include *Remote Aerial Vehicle Information Network (RAVIN)*, *“Soccerball” Small Distributed Phased-Array Jammer*, *Civil Infrastructure: Autonomous Support for HA/DR*, *Ground Surveillance System Deployable ISR Packages*, and *the Robotic Self-Healing Mesh Network*.

2. Innovative Undersea Warfare: These concepts leverage autonomy to clear and secure sea lanes and harbor approaches for landing and resupply in a contested urban littoral environment. Concepts in this category include *HYDRA Shield* and *Autonomous Guard*.

3. Autonomous Unmanned Submersible Missions: These concepts employ autonomy to leverage or disable all available assets in a contested urban littoral environment. Concepts in this category include *USVs of Opportunity* and *“The Heisman” Autonomous Bumper Boat*. (CRUSER 2016)

b. WIC Workshop Results

The four-day effort culminated in presentations to military and industrial leaders, highlighting complex, innovative, and synergistic solutions to these main topics. A final *For Official Use Only* (FOUO) report was generated based on the work and is available

to authorized users. The results of this continuum align with the CNO's vision and lay the groundwork for this report.

E. SYSTEMS ENGINEERING

Early on in the graduate program, the team learned several accepted definitions of “systems engineering” and unique tenets apply to the field. The preeminent governing body of systems engineering, the International Council on Systems Engineering (INCOSE), has published a thorough and widely used definition. According to the INCOSE website:

Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem:

Operations, Performance, Testing, Manufacturing, Cost and Schedule, Training and Support, and Disposal.

Systems Engineering integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. Systems Engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs. (INCOSE 2017)

1. Process Models

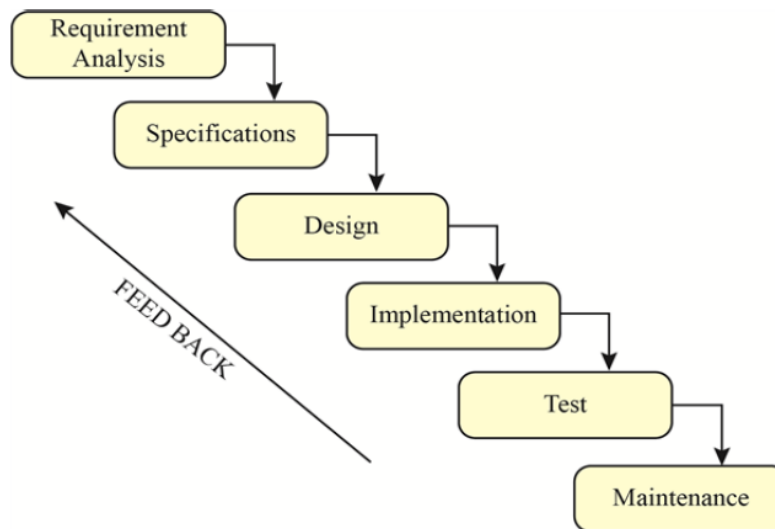
It is very important for the project team to review and understand different types of systems engineering process models in order to choose and apply an appropriate one. There are three well-known systems engineering process models described by Blanchard and Fabrycky's *Systems Engineering and Analysis* textbook. From these process models, the team has selected a systems engineering process model that best supports the project.

a. Waterfall Model

The first systems engineering process model is the waterfall process model. The waterfall model is a linear sequential model. According to Blanchard and Fabrycky, “this model consists of five to seven series of steps or phases for systems engineering or

software development and each phase is carried out to completion in sequence until the product is delivered” (Blanchard and Fabrycky 2011, 36).

Ideally, this is the most efficient process model; however, in reality issues always come up during the systems engineering process. Based on this model, problems are not discovered until the next phase is delayed or the system is completed. As a result, this model lacks the flexibility for instant feedback throughout the entire process. Nevertheless, in this project, the team requires adopting a systems engineering process model that provides flexibility and feedback throughout that process to develop the desired system. The waterfall model is shown in Figure 2.



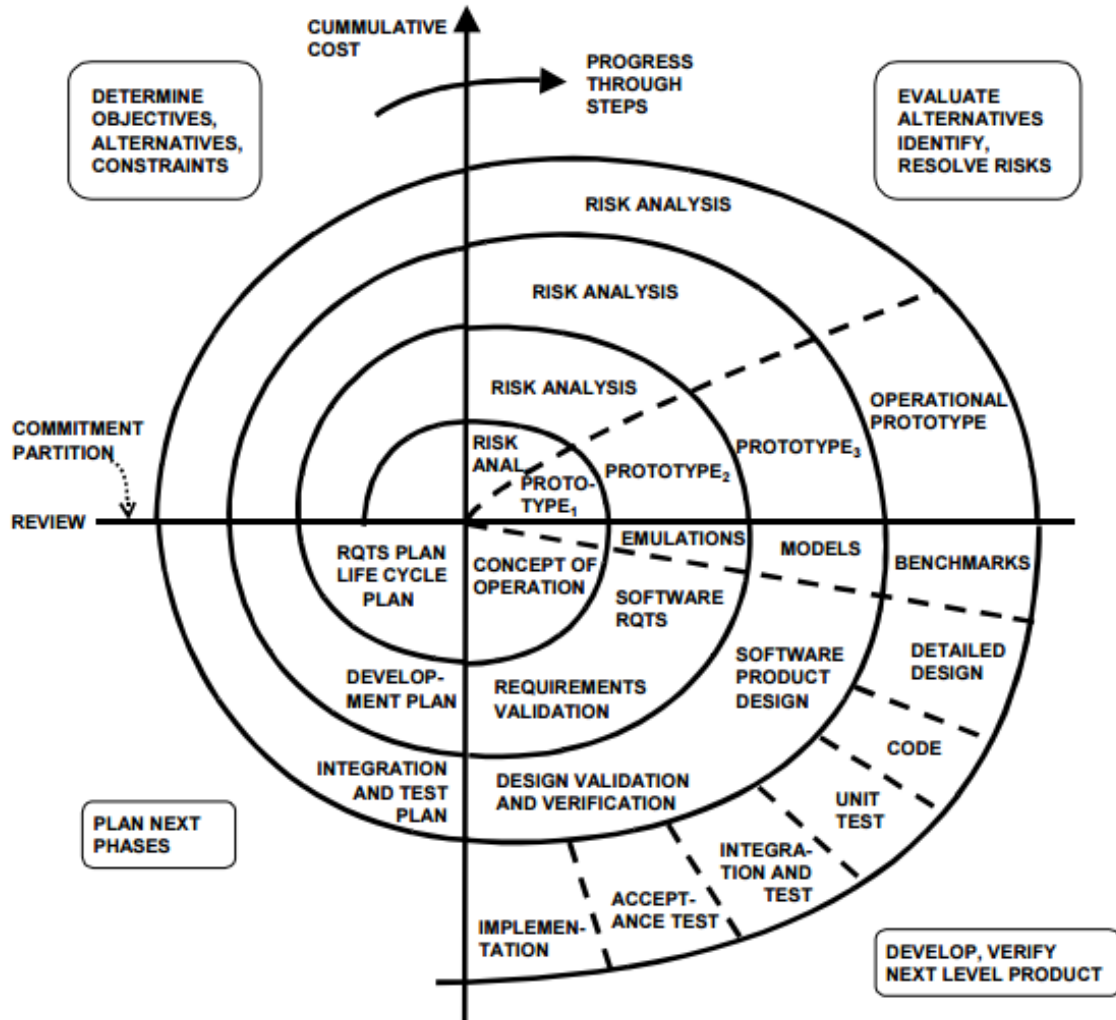
Adapted from Blanchard and Fabrycky (2011).

Figure 2. Waterfall Process Model.

b. Spiral Model

The second systems engineering process model is the spiral process model. According to Blanchard and Fabrycky, “the spiral model is an adaptation of the waterfall model and it incorporates feedback into the process. It is iterative and proceeds through several phases each time a different type of prototype is developed” (Blanchard and Fabrycky 2011, 37).

This model is known to be very time consuming and difficult to manage. Due to the compressed nature of the project tasking, the team requires a systems engineering process model that is less time consuming and more manageable throughout the systems engineering process, and therefore the team did not choose this model. The spiral model is shown in Figure 3.

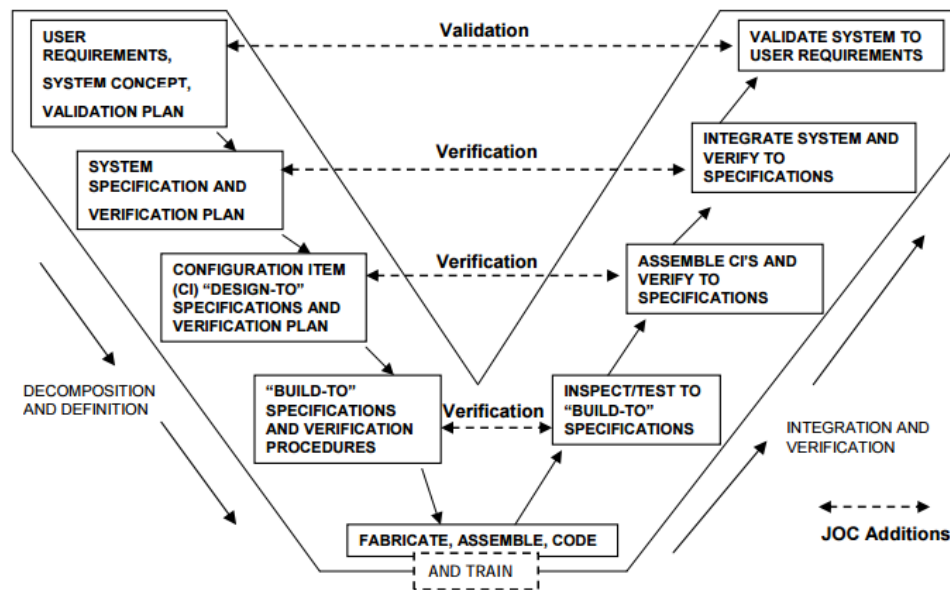


Source: Boehm (2000).

Figure 3. Spiral Process Model.

c. ***“Vee” Model***

The third systems engineering process model is the “Vee” process model. The “Vee” model is an extension of the waterfall model and incorporates feedback loops throughout the process. According to Blanchard and Fabrycky, “this model starts with user needs on the upper left, proceeds down the left side of the “Vee” and across at each level, ending with a user-validated system on the upper right” (Blanchard and Fabrycky 2011, 37). This model is less time consuming than the spiral model. Based on these advantages, the “Vee” model is most suited for the capstone project. A graphic depiction of the “Vee” model is shown in Figure 4.



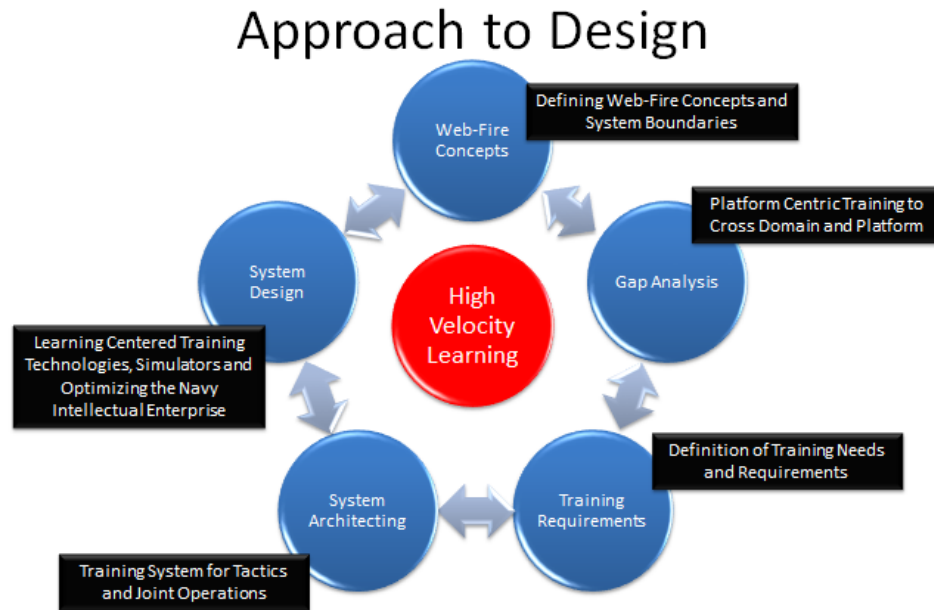
Source: Clark (2009).

Figure 4. “Vee” Process Model.

2. Selected Design Approach

The team approached the training system design with a five-step process most similar to the “Vee” model. The first step is to clearly define the webfires concepts and identify its boundaries so that its training requirements are identified. The second step is to conduct gap analysis on current platform-centric training and compare it to webfires required training in order to leverage cross-domain and cross-platform technologies. The

third step is to understand the training needs and generate thorough training requirements. The fourth step is to develop a training system architecture. The fifth step is to produce a complete training system design to support webfires concepts. These steps occur iteratively until the proposed system architecture satisfies all of the defined needs and requirements of the system. The selected system design approach is shown in Figure 5.



Entry into the cycle occurs at “Webfires Concepts” and proceeds clockwise around, finishing at “System Design.” However, each double arrow represents an iterative process that may require revisiting previously completed steps.

Figure 5. System Design Approach

II. PROBLEM DEFINITION

According to *Systems Engineering and Analysis*, “The systems engineering process generally commences with the identification of a ‘want’ or ‘desire’ for something based on some ‘real’ deficiency” (Blanchard and Fabrycky 2011, 57). Often times, the stakeholder has a want or a desire to fix a specific deficiency, but may not truly understand the actual nature of the deficiency. That is why as part of the systems engineering process, stakeholders must be interviewed to aid the systems engineers in determining a “comprehensive statement of the problem [with] specific qualitative and quantitative terms and in enough detail to [define the] ‘real’ problem and its importance” (57).

A. TASKING STATEMENT AND PROBLEM STATEMENT

In October of 2016, the team received its tasking statement from OPNAV N9I, the government sponsor for the Systems Engineering Analysis Curriculum and the primary stakeholder for this project. The official tasking statement is in APPENDIX A. After receiving the tasking statement, the team established smaller working groups in order to research, identify, and interview stakeholders; make critical assumptions; and scope the project to an appropriate level. Through this process, the team was able to discern and analyze the underlying problem that this capstone project addresses.

1. Tasking Statement

Design a fleet system of systems and concept of operations for employment of a cost effective training system capable of preparing naval warfighters to employ and leverage the webfires concepts and technologies in the 2025–2030 timeframe.

- Consider training across warfare missions and specialties.
- Conduct research to provide a solid foundation of knowledge requirements for a webfires fleet concept.
- Complete a gap analysis by comparing current fleet training with the required training to leverage cross-domain and cross-platform capabilities in a warfighting environment.

- Scan for current examples of cross-domain training and current training simulation from DOD and industry.
- Develop a system architecture addressing responsible command, training requirements, training and exercise venues, and training participants to fill discovered gaps in meeting the knowledge requirements.
- Assess the proposed system against the principles of high-velocity learning found in the CNO's *A Design for Maintaining Maritime Superiority*. (Appendix A)

The italicized and underlined text of the tasking statement indicates the topics that the team focused and built upon. The tasking statement identified several key aspects that the team used to conduct research, outline stakeholder interviews, and develop critical assumptions. The analysis of the tasking statement enabled the creation of the actual problem statement that gives direction and scope to capstone the report.

2. Problem Statement

Through the process just delineated, the team crafted the following problem statement:

Develop a cost-effective operational training system architecture for a webfires concept. The system architecture will help support training on webfires specific evolutions during the basic, integrated, and sustainment phases of the OFRP. The proposed training system will enable CSG/ESG units to successfully conduct missions in the 2025–2030 timeframe by leveraging high-velocity learning with current and future technology.

This chapter also provides definitions of key terms: *Cost Effective*, *Webfires*, and *High-Velocity Learning*. These definitions support an understanding of the terminology used with respect to this research. Additionally, critical assumptions and boundaries are defined and discussed in order to effectively scope this report.

B. ASSUMPTIONS

According to *The Thinkers Guide to Engineering Reasoning*, “Reasoning can be only as sound as the assumptions on which it is based” (Paul, Niewoehner, and Elder

2013, 36). Therefore, it is important that engineers are clear about the assumptions they make, that the reasons for the assumptions are justifiable given the problem, and that the assumptions are consistent with each other (2013). The assumptions for this report are listed in Table 4.

Table 4. Assumptions

| <u>Critical Assumption</u> | <u>Justification</u> |
|-----------------------------------|---|
| Funding | The Navy has the intention of developing and investing in a webfires concept, and there will be a need for training system. Therefore, it is assumed that the Navy will provide resources necessary to develop such a training system. |
| Fully Developed Tactics | The webfires concept is being developed by multiple organizations, while the Warfare Development Centers (WDCs) are working on the technology and tactics that are associated with implementing the system. By the year 2025–2030 it is assumed that the webfires concept will have been integrated into the fleet and that the tactics, doctrine, and procedures will exist. |
| Current Training Infrastructure | The current training infrastructure (schoolhouses, simulators, and other training facilities) will support the proposed WFTS. |
| Webfires Relevancy | Based on the enemy threat and the need for the Navy to continually maintain and advance maritime superiority, webfires will aid in this ability and will therefore still be applicable to the Navy in the future. |
| Personnel Requirements | Personnel requirements to support webfires will not drastically affect the current Navy personnel requirements. This does not assume any change in future manpower requirements. |
| Future Technology | Evolutionary technology and assumed technological advancements that will occur between now and the years 2025–2030 in support of such a training system will be produced using these assumed technologies. |

C. BOUNDARIES

Boundaries are understood as a defined limit to an area. When applying this definition to an engineering problem, boundaries define the limits of that problem. By

making appropriate assumptions and defining realistic boundaries in accordance with the problem statement, engineers are able to scope a problem in a way that allows a realistic solution to be drafted. The boundaries for this report are listed in Table 5.

Table 5. Boundaries

| <i>Critical Boundary</i> | <i>Justification</i> |
|---------------------------------|---|
| Administrative Boundaries | The team will only look at the Fleet Forces Command level and below with respect to the administrative boundaries of the system. Incorporating higher administrative levels, to include joint units and other DOD entities, would unnecessarily complicate and increase the scope of the project. |
| Operational Boundary | The team will only look at the Commandant Command level and below with respect to the operational boundaries of the system. Incorporating a higher national command perspective would unnecessarily increase the scope of the project. |
| CSG/ESG Units | While the concept of webfires may eventually be applied to interactions between joint services and allied nations, for the purpose of this project, the scope will be limited to units and training entities comprised of and integral to the training of a Carrier Strike Group (CSG) and/or Expeditionary Strike Group (ESG). |
| Cyber Domain (non-focus) | The webfires concept and Training System will rely heavily on the ability to share information in cyber domain. The team's focus is to develop a training architecture that considers cyber implications and information security; however, the actual creation of information safeguards would be outside the scope of the research. |

D. DEFINITIONS

The following definitions aid the reader in the understanding of some key terms in this report.

1. Cost Effective

Most definitions of cost effectiveness revolve around some variation of achieving the highest (or desired) quality for the lowest cost. Of course, the terms “desired value” and “low cost” can have various interpretations across individuals, situations, and

applications. Therefore, cost effectiveness is an especially vague term that can take on several different meanings depending on the context, and it is more specifically defined relative to this project.

Whatever method one might use to determine cost effectiveness, it generally encompasses a multi-faceted comparison of costs and performance. For example, cost effectiveness can be related to the cost of a project through the total allowed budget. Using this example, a solution must cost at or below budget to be considered cost effective. Another method to determine cost effectiveness is more qualitative, such as how a proposed solution compares to the current method of doing business, or how a proposed solution compares to other alternative solutions in a solution space.

For this capstone project, a specific budget is not officially available, and a lack of comparisons to an allowed budget will not be a constraint in determining whether a solution is cost effective. Ideally, during the Analysis-of-Alternatives phase, a comparison of the costs and training value for each alternative would be plotted using the Cost as Independent Variable analysis technique. From this plot, the team would be able to determine a cost efficiency frontier to aid in determining which solutions are the most cost effective. Due to the classified nature of the webfires system and high end combat systems simulators, however, specific cost estimates were unattainable for this project. Additionally, other cost concerns should be factored into high-risk applications such as military operations. One particular cost concern is the cost associated with failure. Inadequacies in training can have high costs associated with them, particularly when these training inadequacies result in a loss of multiple units or lives. Even if inadequate training does not lead to the loss of units or lives, there are other, less quantifiable costs, such as degraded mission accomplishment or longer response time in the battlespace.

Due to the complexity of the webfires technology, the inability to obtain cost estimates for high-end combat simulation systems, and the cost uncertainties associated with training inadequacies, the team has decided not to provide specific monetary values for cost effectiveness. This does not mean the need to be cost effective was dismissed when developing a training architecture. Though no quantitative cost effectiveness

argument is presented, the goal of a qualitative cost effective training architecture remained a focus throughout the project.

Some qualitative cost effectiveness can be assumed in that it is desirable for the proposed solution to integrate into the existing training structure delineated in the Optimized Fleet Response Plan (OFRP). It is desirable that the proposed solution incorporate existing training facilities and training networks where feasible, thereby reducing the costs associated with building an entirely new training network. Finally, as simulation technology improves, training facilities will be able to simulate combat scenarios with greater fidelity. In some respects, current simulations can achieve a higher fidelity than is achievable in live exercises, particularly when simulating enemy tactics and weaponry such as missile profiles.

There is potential for large cost savings by not sending an entire strike group underway to conduct a training exercise and instead conducting simulated combat scenarios while in port or at a training facility. Nevertheless, the ability to save money by training pier-side instead of underway does not imply that all underway training should be replaced with in-port training for the sake of cost effectiveness.

2. Webfires

The U.S. Navy has traditionally engaged enemy targets utilizing a linear kill chain process. This structure of attack, as described by Admiral Greenert, consists of four steps and is pictured in Figure 6:

1. Find the target.
2. Determine target's location, course, and speed.
3. Communicate that information coherently to the platform launching the weapon.
4. Launch the attack using anything from a kinetic weapon to electromagnetic systems to cyber. (Greenert 2013)

This integrated attack profile has a number of flaws. Any disruption within the four-step process will render the attack incomplete. For this reason, the process is commonly named a kill chain, as any removed link will break the chain. As our efforts

abroad work to exploit these weaknesses in adversarial weapon systems, it would be naïve to assume the enemy is not trying to do the same to our weapon systems. The kill chain process now expands beyond the battlefield into the cyber domain, and requires significant investment in the area (Hutchins, Cloppert and Amin 2017).



Adapted from Greenert (2013).

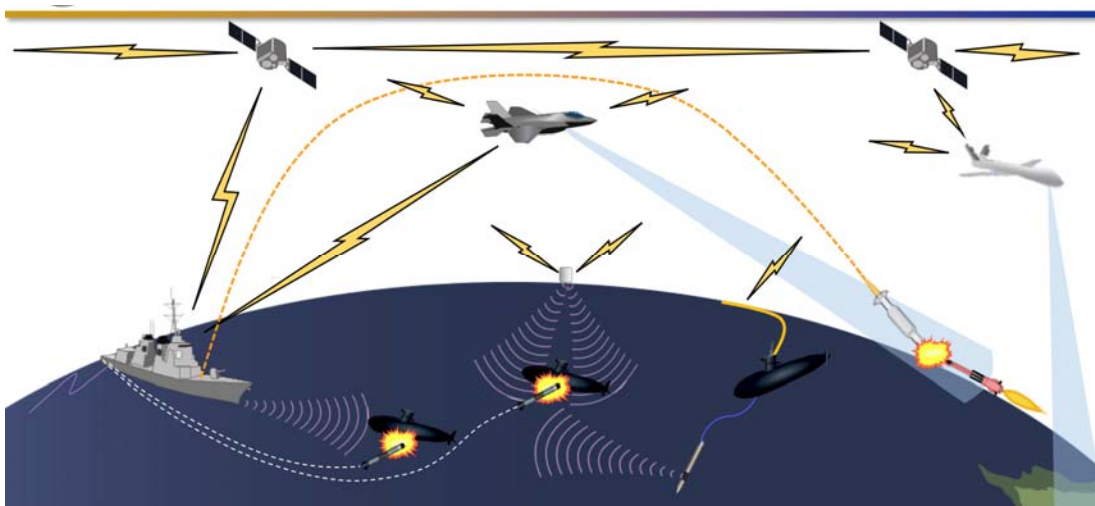
Figure 6. Traditional Kill Chain Approach.

To combat the enemy's attempts to disrupt our kill chain process, and to expand the Navy's offensive command and control (C2) capabilities, the DOD has invested heavily into integrated fires concepts, such as kill-webs. As described by Rear Admiral Manazir in 2016:

The Navy has many effective kill chains—a sensor that provides targeting data to a platform that can then launch a weapon against a target—in the air, ground, surface and undersea domains. The service has even made progress netting together some of these kill chains within a single domain, bringing together airplanes that rely on different communications waveforms and were not built to be interoperable, such as a recent effort to bring the F-35 Joint Strike Fighter and its unique Multifunction Advanced Data Link (MADL) communications into the Naval Integrated Fire Control-Counter Air (NIFC-CA) architecture.

Now, these kill chains need to be strung together to create a cross-domain kill web, enabling any plane or any ship to pull information from whatever sensor happens to have relevant data, regardless of domain.

Figure 7 depicts Admiral Manazir's concept for networked warfare and is used as the basic concept for webfires in this report. This webfires Operational View (OV-1) provides a standard DOD Architecture Framework (DoDAF), or basic engineering view of the system of systems architecture behind kill webs and the precursor system to webfires. Traditionally, each unit would operate independently, only utilizing onboard sensors and weapons. For example, the F-35 pictured at the top of the figure would utilize a kill chain that would find the target using onboard radars or cameras. Next, the onboard computer would calculate the onboard missiles launch profile. The pilot would launch the missile once instructed to do so.



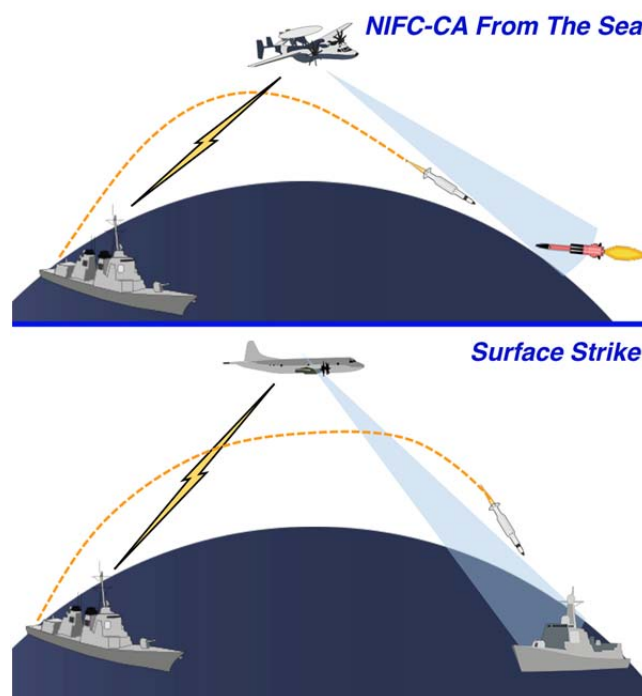
Adapted from Manazir (2016).

Figure 7. Networked Warfare.

Now each step in the engagement sequence, utilizing a kill web, would include additional sensors or weapons that give the best situational awareness or tactical ability to strike the target. For example, the destroyer shown in Figure 7 could utilize the over-the-horizon radar capability of the F-35 for targeting information and launch an offensive weapon against a threat that would otherwise be impossible for the destroyer to detect.

One example of kill webs currently under advanced development for the carrier strike group is the Naval Integrated Fire Control – Counter Air (NIFC-CA). Although the technical aspects of the program are classified, in general, NIFC-CA provides a

situational awareness and extended-range cooperative targeting capability currently unavailable to the strike group. Another possible use of the NIFC-CA concept would be to expand the scenario depicted in Figure 7, where an airborne unit identifies, tracks, and targets an incoming missile for the surface ship. The surface ship then fires a defensive weapon utilizing the airborne unit's targeting information to defeat the threat. A different scenario would be to use the airborne unit's targeting information to launch an offensive weapon instead. These scenarios are shown in Figure 8.



Adapted from Manazir (2016).

Figure 8. NIFC-CA Scenarios.

Rear Admiral Manazir has stated “every unit within the carrier strike group—in the air, on the surface, or under water—would be networked through a series of existing and planned datalinks so the carrier strike group commander has as clear a picture as possible of the battle-space” (Majumdar and LaGrone 2014). Each unit within the strike group has a unique role in a kill web. Each unit acts as a communication stepping stone for other units; this is accomplished through the proper utilization of a series of

waveforms. The current datalinks associated with high-bandwidth communication are displayed in Figure 9.

| | |
|--|--|
| TTNT —the TTNT is long-range, low latency, high throughput data-link that will link together the critical nodes of NIFC-CA. These include the E-2D, carrier, UCLASS and possibly the EA-18G. | Link-16/CMN-4 —this advanced version of Link-16 is a potential alternative to TTNT on the Growler. Basically, it is four Link-16 systems running concurrently. |
| Link-16 —Link16 is the standard data-link used by NATO. The Super Hornet will be communicate via this data-link since it does not need the data throughput levels of some of the other aircraft such as the E-2D. | Advanced Tactical Data-link —The F-35C will need a long-range, low-probability of intercept, jam-resistant data-link to relay its targeting data back to the E-2D. Lockheed Martin is working on the capability for the jet's Block IV configuration. |

Adapted from Majumdar and LaGrone (2014).

Figure 9. Webfires Datalinks.

3. High-Velocity Learning

To continue to meet the commitments of the nation at an affordable price-point, the U.S. Navy must adjust its ability to learn and train to the evolving maritime security environment. It must adopt more innovative and intuitive learning models in order to maintain a fleet ready to operate, fight, and win decisively. As described in the CNO's vision (Richardson 2016), to achieve high-velocity learning the U.S. Navy will:

Apply the best concepts, techniques and technologies to accelerate learning as individuals, teams and organizations. Clearly know the objective and the theoretical limits of performance—set aspirational goals. Begin problem definition by studying history—do not relearn old lessons. Start by seeing what you can accomplish without additional resources. During execution, conduct routine and rigorous self-assessment. Adapt processes to be inherently receptive to innovation and creativity.

1. Implement individual, team, and organizational best practices to inculcate high-velocity learning as a matter of routine.
2. Expand the use of learning-centered technologies, simulators, online gaming, analytics, and other tools as a means to bring in creativity, operational agility and insight.

3. Optimize the Navy intellectual enterprise to maximize combat effectiveness and efficiency. Reinvigorate an assessment culture and processes.

4. Understand the lessons of history so as not to relearn them. (2016, 7)

Traditionally, the U.S. Navy is a highly structured institution with deep rooted learning and training habits. “Most organizations are hindered by a structural problem: they manage their functions individually, not as steps in a well-integrated process. Each function does its job and somehow the whole thing comes together—except when it doesn’t” (Spear 2009, 357).

High-velocity learning allows for better management of individual functions as they apply to the overall operation. Within the webfires concept, utilizing a high-velocity learning approach can better ensure sailors receive relevant and accurate knowledge throughout their individual and integrated training. This approach not only increases a sailor’s likelihood of being successful, but also increases the individual’s opportunity to learn. A model of the high-velocity learning process is summarized by Spear (2009) below and illustrated in Figure 10.

Rather than letting each experience be either a success or a failure—but in neither case improving anyone’s chance of success on the next try [see *Figure 9–1*—every experience is designed to increase the likelihood of success on the next try as knowledge and know-how accumulate [see *Figure 9–2*]. (118)

Figure 9-1 Succeed or fail

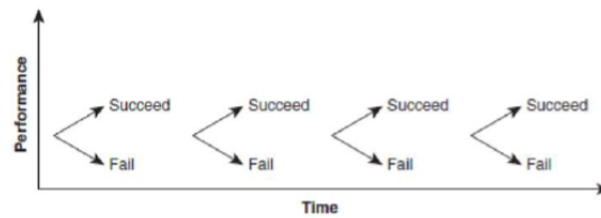
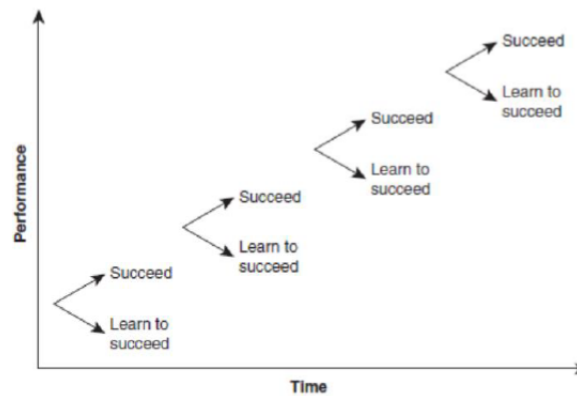


Figure 9-2 Succeed or learn to succeed



Source: Spear (2009).

Figure 10. Likelihood of Success.

Technology continues to develop at an exponentially faster rate; the currently outdated and rigorously structured learning model places sailors at a severe disadvantage in the operational environment. It is vital to mission success that equal importance is applied toward both developing the technical competency to perform various functions and the way that watch standers, watch teams, and technologies contribute to the operation of which they are a part.

Highlighted in the early parts of the essay *A Naturalistic Study of Insight*, two efforts that can enhance human performance during high-velocity learning include reducing the number of mistakes and by increasing insights (Klein and Jarosz 2011). Many examples illustrate the bureaucratic and systemic lop-sided focus on the first effort over the second. According to Klein and Jarosz, the complaint that typically emerges from this imbalance centers on students' failure to gain problem-solving insights due to

limited time, resources, and attention caused by the undue emphasis on reducing mistakes (2011).

4. Types of Training

The Navy, as a whole, conducts many different types of training. For the purpose of this report, training is divided into three essential types: individual, unit, and multi-unit training.

a. Individual Training

Individual training is training that the Navy provides officers and sailors to prepare them to perform their specific occupational duties and attain their initial qualifications. This type of training focuses on the individual and can consist of classroom instruction, simulator time, or other forms of occupational training.

b. Unit Training

Unit training is the type of training that units perform as a whole to train their watch teams and sailors to work together to perform missions that a unit would be expected to perform. This training focuses more on team performance and less on individuals.

c. Multi-Unit Training

Multi-unit training is the type of training that focuses on units being able to perform missions with other units. The number of units involved in this training can range from as few as two (such as a surface ship conducting an anti-submarine warfare mission with a helicopter) to a full-scale strike-group exercise comprised of an air wing, multiple surface ships, submarines, or various combinations of such assets.

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III. NEEDS ANALYSIS

A. STAKEHOLDER ANALYSIS

Stakeholder analysis is a tool to help the systems engineer better understand the problem at hand. Primary reasons for conducting stakeholder analysis include: to identify the people and organizations relevant to the problem, and to determine their needs, wants, and desires with respect to the project outcome. A secondary purpose is to start identifying critical assumptions and constraints on the problem. At the conclusion of this analysis, the systems engineer should have a better understanding of the real problem at hand. This analysis is derived in the form of a revised problem statement.

The revised problem statement clearly outlines the true underlying needs of the client. Solving the revised problem statement is the objective that the proposed design architecture strives to obtain. This is the critical point on which the rest of the solution is built. To develop a satisfactory problem statement for the client, the systems engineer must conduct the stakeholder analysis properly. Failure to identify the correct problem or failure to identify the correct needs from the stakeholders could result in delivering the client a solution to the wrong problem as well as wasted resources along the way. The typical steps involved in stakeholder analysis are described in the following paragraphs.

(1) Identify the Problem

An initial problem statement is usually provided to the systems engineer by the client. The initial problem statement received from the client, however, is often vague or under-developed. Often clients do not know what it is that they really want or need. This can be expected because clients do not perform their own needs analysis, do not talk to the other stakeholders involved, and often do not know what feasible solutions exist. That is why the client seeks the expertise of someone familiar with these processes: the systems engineer. It is up to the engineer to identify and define the root problem.

(2) Identify Relevant Stakeholders

Once the initial problem is identified, its definition will need to be refined. While the systems engineer may be an expert in the system design process, he or she is usually not an expert in the content area of the specific problem. For this reason, individuals with expertise in the subject matter related to the problem are often included as stakeholders.

The name stakeholder comes from the vested interest or personal stake these groups or people have in the problem or its solution. Stakeholders are typically classified into one of several categories: clients, sponsors, decision makers, users, and analysts. It is the systems engineer's task to identify likely stakeholders so that they may be contacted to provide some additional insight into the requirements and needs that the solution must address.

(3) Develop a List of Questions or Desired Information and Conduct Research on the Problem

Stakeholders do not always know what they want the solution to be, or what solutions are even feasible. It is the task of the systems engineer to research the problem and determine what additional information is needed from the relevant stakeholders to scope the problem space and generate an actionable requirements list.

(4) Conduct Interviews

After identifying who the stakeholders are, and developing questions to determine their needs, wants, and desires as they pertain to the problem at hand, the next major step is to collect information from the stakeholders. This is done by contacting the stakeholders directly to receive their inputs into the problem and what they might like to see in a solution. This stakeholder input helps to identify the "gap" between the current situation and the desired situation, where the "gap" represents the true needs of the solution.

(5) Consolidate Information Gained

Individual stakeholders do not always have the same needs as other stakeholders. Specifically, the end user may have different needs from the client providing the initial

problem, or even the sponsor paying for the solution. Stakeholder analysis provides a method for compromise between the needs of multiple stakeholders. This is achieved when the information from all of the stakeholders is obtained and consolidated into one needs statement.

(6) Iterate as Necessary

It is highly unlikely that all of the required information will be obtained in the first phase of stakeholder research. It is likely new questions will continue to arise throughout the project. Stakeholder analysis is conducted as an iterative process. As new information from the stakeholders is gathered, this information is then added to the requirements generation process.

B. STAKEHOLDER IDENTIFICATION

As part of any successful systems engineering project, requirements must be harvested, analyzed, and subsequently met by the proposed system; the key engagement must be with, and for, the stakeholders. In addition to the primary stakeholder, OPNAV N9I, the team identified key stakeholders to interview within two primary geographical areas: Fallon, NV, and San Diego, CA. During one of NPS's thesis and research weeks (March 2017), the team conducted site visits to the commands shown in Table 6. The commands identified represent the points-of-view necessary for a majority of the stakeholder requirements.

Table 6. Interviewed Stakeholders

| <u><i>Command</i></u> | <u><i>Location</i></u> |
|---|------------------------|
| Naval Aviation Warfighting Development Center (NAWDC) | Fallon, NV |
| Tactical Training Group, Pacific (TTGP) | San Diego, CA |
| Naval Surface and Mine Warfighting Development Center (SMWDC) | San Diego, CA |
| Expeditionary Warfare Training Group, Pacific (EWTGPAC) | San Diego, CA |
| Third Fleet (COMTHIRDFLEET) | San Diego, CA |
| Commander, Naval Surface Forces Pacific (COMNAVSURFPAC) | San Diego, CA |

Per NPS protocol, it is imperative that all questions to stakeholders first receive approval by an Institutional Review Board (IRB) to ensure the project is the intended focus and there is no inadvertent human research without the proper procedures in place. The team generated a list of stakeholder questions and submitted them to the IRB and SEA Chair prior to visiting. The questions were determined to not contain human subject research in any form. A list of the IRB approved questions and associated IRB documentation appear in Appendix E.

1. Naval Air Warfare Development Center

The primary mission of NAWDC is to provide aviation flight training, academic instruction, and operational and intelligence support for all aviation platforms throughout the Navy (CNIC 2017). Along with development and updating of Tactics, Techniques, and Procedures (TTPs) for aviation mission areas, NAWDC provides subject matter experts (SMEs) to major commands that support the OFRP training continuum throughout the world (2017).

The team noted the following significant observations from NAWDC:

- NAWDC engages in integrated training primarily through established systems such as NIFC-CA. This system has had significant impact on the operations on the tactical and operational level.
- Debriefing of training events conducted at NAWDC is accomplished in one room, with all players in a face-to-face environment. This tends to provide positive training, with all assets able to follow thought processes and resulting actions that occurred and is facilitated by local SMEs. The environment especially allows for common references, increased synergy, and creative/unique perspectives from various platforms. Improvements needed include increased man-machine interfaces, better communication systems, higher fidelity, and inclusion of key warfighters involved in tactical decisions.
- Intelligence updates lag due to lack of direct input and resultant changes to the TTPs. This is primarily due to security concerns and human interaction required to determine importance and effectiveness.
- Recorded data analysis lags behind the real-time tactical engagements resulting in unknown effectiveness. During training, operators must use estimates and models to evaluate performance.

- There is a significant effort to integrate real and simulated world, such as with Aegis Air Defense with aircraft, but there is a concern with security and data integrity.
- There is currently no training timeline that unifies the phases of the OFRP across multiple domains nor an established command responsibility for integrated training requirements.
- Geographically, Fallon, NV, is secluded from the major fleet concentrations, and only a limited number of personnel are currently available to be sent from commands for extended periods of integrated training.

2. Tactical Training Group, Pacific

The Tactical Training Group, Pacific (TTGP), along with its East-coast counterpart, Tactical Training Group, Atlantic (TTGL), provides tactical training in support of the OFRP training, specifically for and within the numbered fleets (U.S. Navy 2017b). They establish and present curricula, interactive simulations, and innovative feedback for customers (2017b). They coordinate with Commander, Carrier Strike Group Fifteen (CSG-15) for underway training.

The team noted the following significant observations from TTGP:

- Live Virtual Constructive (LVC) training has many different interpretations. There is little standardization for what constitutes an LVC training event within tactical syllabi; scenarios take up to a full year to develop.
- Weapons and Tactics Instructors (WTI) as seen in the aviation community has become a “best-practice” model that surface vessels are implementing.
- Networks such as the Navy Continuous Training Environment and Joint Semi-Automatic Forces (JSAF) provide more information and quicker interaction for warfighters to recognize enemy/friendly forces and engage more effectively, but are currently platform limited by the high cost of implementation at a tactical level. Red force players are currently trained personnel, with no AI component.
- Fleet Synthetic Training (FST) requires robust communication networks and bandwidth and currently is limited to CONUS locations.
- Commands interested in TTGP training lack resources and people to send temporarily for on-site training, and they currently are limited in connecting trainers at tactical locations.

3. Surface and Mine Warfare Development Center

The Surface and Mine Warfare Development Center (SMWDC) concentrates on the surface warfare community's tactical training in six core areas, including Amphibious Warfare, Air Warfare, Ballistic Missile Defense Mine Warfare, Missions of State, and Surface/Anti-submarine Warfare (SMWDC 2017). It supports training individuals in the OFRP by developing, improving, and integrating surface warfare doctrine.

The team noted the following significant observations from SMWDC:

- Surface community is currently attempting standardization through the use of the Surface Warfare Combat Training Continuum and Surface Warfare Advanced Tactical Training programs.
- Adaptation to other communities' best practices has worked and is currently underway in the surface community to establish a cadre of recognized tactical SMEs for standardized warfare training.

4. Expeditionary Warfare Training Group

The Expeditionary Warfare Training Group (EWTG) conducts mostly classroom-centric training and instruction to support amphibious expeditionary warfare operations that support the U.S. Navy's mission of projection of power from the sea. In addition to construction and modifications of TTPs, EWTG employs SMEs in the realm of modeling and simulation providing realistic synthetic training (U.S. Navy 2017a).

The team noted the following significant observations from EWTG:

- Differing infrastructure and communication networks, especially between the United States Marine Corps (USMC) and USN units, complicates coordination between existing systems. For example, this has been seen in Marine Air-Ground Task Force Tactical Warfare Simulation (MTWS) and JSAF.
- Significant resources are lacking, especially for personnel considering career timing and availability for onsite training (for both student and instructor roles). Infrastructure and funding does not exist for the establishment of simulators to be placed with all units that could benefit from them.
- The acquisition process does not integrate with other projects that are either already established or in the process of being developed.

- Senior leadership misinterprets the ability to integrate current commercial programs into military training, as computer technology and infrastructure in military systems are severely lacking the resources to do so; there is a search for solutions that lack requirements.
- Integration between USN and USMC forces has suffered due to lack of USN personnel billeted to the command.

5. Commander, U.S. Third Fleet

While one of five numbered fleets, Commander, U.S. Third Fleet (COMTHIRDFLT) is responsible for maintenance, operations, and training of the Pacific Fleet and seaward approaches to the western United States (Global Security 2017b). Additionally, as a Joint Task Force commander, COMTHIRDFLT is directly affected by and responsible for integrated tactical training in conjunction with each subordinate command's OFRP cycle (2017b).

The team noted the following significant observations from COMTHIRDFLT:

- Management of individual projected rotation date either coming or leaving the command is essential for assuring readiness or maintaining qualified warfighters.
- NEC codes do not allow for retraining on new and improved technologies, requiring more on-the-job training, less effective learning, and an imbalance of practical knowledge within and between watch teams.
- NIFC-CA is operational only in a Live environment and networks such as Baseline 9 do not integrate in FST environments. Significant Information Assurance (IA) problems exist between broadcasted and implemented tactics and established networks.
- Costs to send vessels underway to train are prohibitive. There would be significant cost savings in establishing quality underway training without leaving the pier.
- Objectives for training are needed, no matter what phase of the OFRP is being executed.

6. Commander, Naval Surface Force, U.S. Pacific Fleet

Commander, Naval Surface Force, U.S. Pacific Fleet (COMNAVSURFPAC) is the primary entity ensuring that surface forces operating in the Pacific and Indian Oceans

have completed all training, maintenance, and manning requirements to operate in joint and cooperative efforts to support the Navy's global missions (Global Security 2017a). Additionally, within the command's hierarchy is the Distributed Lethality Task Force—the U.S. Navy's concept of increasing offensive capabilities of ships while spreading the units' formation in a synergistic fashion (Rowden, Gumataotao and Fanta 2015).

The team noted the following significant observations from COMNAVSURFPAC:

- Current communication networks are not real time and require specific encoding/decoding that is not compatible with budding technologies and threats. This results in an integration and interoperability problem.
- As newer technology solves these issues or webfires concepts advance, a central training network/facility will provide benefits.
- A recognized lack of in-person debrief from multiple platforms is acknowledged. There is a need to adopt SMWDC's Plan, Brief, Execute, Debrief (PBED) cycle for all integrated training evolutions.
- Significant procurement and acquisition problems result in integration concerns.
- It is not necessary to reinvent what actually exists; foreign navies have figured out certain tools to facilitate the PBED process.
- Tactical integration is not being addressed above the Type Commander (TYCOM) level, but remains a requirement.

IV. CURRENT TRAINING PROCESS

Training sailors and Marines to perform tasks in support of CSG or ESG missions is a complex assignment. Considerable repetition is needed for personnel to reach the required individual training level for combat effectiveness and to support the unit's missions. Additionally, considerable time must be set aside for entire training units to work with other units that support larger integrated and complex operations. To address the demands placed upon the force, the Navy has created a revised OFRP, which provides "continuous availability of manned, maintained, equipped, and trained Navy forces capable of surging forward on short notice while also maintaining long-term sustainability of the force" (Howard 2014). This chapter discusses how the Navy currently trains individuals, in addition to how the Navy trains and manages the Fleet in order to provide a "flexible force to respond to combatant commander [needs]" (Howard 2014).

A. INDIVIDUAL TRAINING

The following sections detail how individual sailors and officers are trained to operate and maintain combat systems in each community. For the purpose of this section, only personnel with responsibilities that relate to a submarine, aircraft, or ship's combat systems are examined.

Regardless of the warfare area or community, officer training focuses on the skills and knowledge that officers must have, whereas enlisted training focuses on the skills and knowledge that sailors within various ratings must possess, and combined training focuses on watch team training.

1. Undersea Warfare Domain

Naval officers who volunteer for the Submarine Force must go through the Nuclear Power Training Course and the Submarine Officer Basic Course prior to arrival at their first submarine command. Nuclear power training focuses on the skills that an officer must possess in order to maintain and operate the nuclear reactor onboard

submarines. The Submarine Officer Basic Course focuses on the knowledge and leadership skills that an officer must possess for basic submarine navigation, contact management, and warfare tactics.

Once officers complete both training courses, they are sent to their first command. While stationed there, officers must go through a warfare qualification process. This qualification process ends with being qualified in three positions: Surface Officer of the Deck, Submerged Officer of the Deck, and Qualified Submarines, or “earning the dolphins.” During this qualification process, officers must demonstrate the ability to conduct contact management, submarine navigation, and warfare tactics in a real world environment. After an officer has completed the initial sea tour he or she must go to the Submarine Officer Advanced Course prior to returning to the fleet. This course expands the knowledge and skills that an officer learned during that first sea tour. During this phase of training there is a larger focus on warfare skills and tactics.

Following boot camp, enlisted sailors are sent to Groton, CT, for Basic Submarine School where they learn basic damage-control and firefighting skills. Once they have completed Basic Submarine School sailors are assigned their rate. For the purpose of this report, it is one of the combat systems rates, such as Sonar or Fire Control Technician. Both types of technicians are responsible for operating and maintaining the equipment that is associated with submarine weapons systems. Once they have been selected for their rate, these sailors then learn the basic skills and knowledge necessary to operate and maintain a submarine’s weapons systems.

Once these sailors have completed their initial training they are sent to their first sea command. While at their first command, these sailors go through a qualification process that allows them to learn, in an operational environment, the skills required for them to operate the weapon systems.

Officers and enlisted sailors must be evaluated routinely to ensure that they are maintaining the necessary skills and knowledge to operate the submarine effectively. This currency is maintained through the use of proficiency training, examinations, and watch evaluations conducted by superiors.

Both the officer and enlisted training pipelines teach sailors the basic knowledge and skills necessary to employ a submarine in a tactical environment. These pipelines do not focus on combined team or multi-unit training. Each submarine has multiple watch teams composed of officers and enlisted sailors who must work together as a team to tactically employ the ship. To train these watch teams, units use a variety of techniques and equipment. These include walk-throughs, training simulator time, simulated threats using onboard systems, and practice scenarios at sea.

Type commanders routinely use Tactical Readiness Examination Teams to evaluate a ship's training level. More specifically, these teams evaluate the ability of a submarine to conduct combat operations. Additionally, submarines frequently train with Tactical Readiness Examination personnel aboard in order to evaluate the crew and provide recommendations in areas where they need improvement.

2. Air Warfare Domain

The naval aviation career path is only offered to commissioned officers and provides an opportunity to learn to fly while gaining the relevant knowledge required to operate military aircraft in combat operations. This training is not envisioned to include enlisted air warfare rates. A commissioned officer begins the path to becoming a naval aviator in Pensacola, FL, where Student Naval Aviators (SNA) enroll in introductory flight screening (IFS). IFS introduces the SNAs to a civilian flight program where they learn the basics of flying. Each student is afforded 25 hours of single-engine flight time with a minimum of two solo flights (without an instructor) in a civilian trainer aircraft. After successfully completing the requisite flight hours and a Federal Aviation Authority private-pilot knowledge test, the SNA transitions to Aviation Preflight Indoctrination, also located in Pensacola.

Aviation Preflight Indoctrination consists of six weeks of classroom instruction focused on aerodynamics, aircraft systems, meteorology, air navigation, and flight rules and regulations. After the classroom portion, SNAs are provided two weeks of practical training that include land survival, first-aid, physiology, and water survival topics.

Shortly after completing Aviation Preflight Indoctrination, SNAs are enrolled in primary flight training. SNAs will learn to fly the Navy's Beechcraft T-6 Texan II at either Naval Air Station (NAS) Whiting Field, FL, or NAS Corpus Christi, TX.

Primary flight training reinforces basic flight skills learned at IFS while applying additional rigorous military flight standards. Ground school is offered before any student steps into the T-6 Texan II. Basic knowledge, including knowledge of aircraft systems, local flight rules, and emergency procedures, are taught and tested. Next, the Contact phase introduces the SNAs to their first of many military training flights. The basics of takeoffs, landings, stalls, and spins are introduced and practiced. The remainder of flight time is split among the basic instrument phase, aerobatics phase, formation phase, radio instrument navigation phase, night flight phase, and visual navigation.

After successfully completing primary flight training, an SNA graduate will select from a number of flight platforms, such as strike aircraft, E-2/C-2, E-6B mercury, maritime patrol, or helicopters. Each platform consists of a platform-specific flight syllabus performed during advanced flight training.

Strike platform is designed to train future Navy FA-18 C/D, FA-18E/F, EA-18G Growler, and F-35C Lightning II pilots. The students will fly the T-45C and gain further experience with basic flight skills and additional air combat maneuvering (ACM), low-level navigation, tactical formation flying (TACFORM), and carrier qualifications (CQ).

E-2/C-2 platform is designed to provide future E-2/C-2 pilots dual engine experience not obtained in primary flight training. The aircraft utilized is a military variant of the Beechcraft King Air (T-44)

Rotary-wing platform is designed to take a newly minted fixed-wing pilot and impart the fine art of rotary-wing flight. A classically trained helicopter pilot teaches these skills to students flying the mighty TH-57 Sea Ranger. The SNA will learn the unique skills required to fly a helicopter within a relatively short 100 hours of flight time. A few of the training phases include helicopter familiarization, tactics, low-level navigation, formation flight, night flight, and search and rescue.

After completing one of the advanced flight training curricula, the SNA will graduate to become a Naval Aviator, earning his or her Navy “Wings of Gold.” Naval aviators will transition to Fleet Replacement Squadrons where the skills and tactics required to operate fleet aircraft are learned.

3. Surface Warfare Domain

Currently the surface force primarily trains its officers via a combination of schoolhouses and at-sea exercises, with simulator experience as a rare occurrence. Prior to arriving to their first ship, a surface warfare officer (SWO) receives some introductory classroom training on ship systems and duties, but there is little to no focus on combat or tactics at this early stage. After completion of the first division officer tour at sea, a SWO is for more advanced schoolhouse training called Advanced Ship handling and Tactics, but ironically, there is little combat or tactical training involved in this schoolhouse training. At both introductory and Advanced Ship Handling and Tactics training, simulators are used to help train the junior SWOs, but these simulators predominantly focus on ship handling skills and bridge watch-standing coordination. If a SWO is fortunate enough to receive a billet into a combat watch-standing position for his or her second division officer tour, the SWO will likely go to a specialized school. There SWOs receive specific training for the watch station they are expected to qualify for and fill on the ship. At these schools, the training will finally focus on learning tactics. This is taught using a combination of classroom education and tactical simulations of combat scenarios.

The next major milestone of a SWO is the department head (DH) tour. Here every SWO takes tactical responsibility while standing watches as a Tactical Action Officer (TAO) in charge of the ship’s Combat Information Center (CIC). In preparation for this, the future DH receives extensive training and simulations. Once onboard the ship, they receive more realistic training through underway exercises at sea.

A similar training pipeline takes place for prospective commanding officers before they arrive at their next at-sea command. These senior SWOs will attend various schools to acquire the training necessary for commanding a ship, including a tactical simulator experience.

The process for enlisted combat watch stations is similar, with the exception of longer timelines at initial schools in order to learn their rates, and longer tours on any particular ship. The bulk of the training still takes place with classroom education at schoolhouses and real world exercises while underway at sea. Simulators are predominantly used only while pier-side.

One element largely lacking from the current SWO training and enlisted pipelines is widespread use of tactical simulators, except for when conducted at various shore facilities prior to these personnel reporting to their next at-sea command.

B. OPTIMIZED FLEET RESPONSE PLAN

The focus of the OFRP is to “maintain, train, deploy, and sustain readiness when at home ... and yet to optimize that cycle, the Navy must align numerous ‘subordinate processes’ and balance goals of various naval communities, requiring a cross-community collaboration” (Eckstein 2016). By implementing this process, the fleet will “ultimately be better prepared to meet combatant commander needs without straining the ships, planes, and sailors” (Eckstein 2016). The OFRP cycle consists of five phases:

1. Maintenance
2. Basic
3. Integrated
4. Advanced
5. Sustainment

These phases help focus the Navy’s activities and resources with the following lines of effort: “fleet response plan length, command and control (C2) alignment, manning and individual training, maintenance and modernization, logistics, Military Sealift Command (MSC) support, inspections, unit and advanced training, and operational and tactical headquarters training” (Howard 2014, 2).

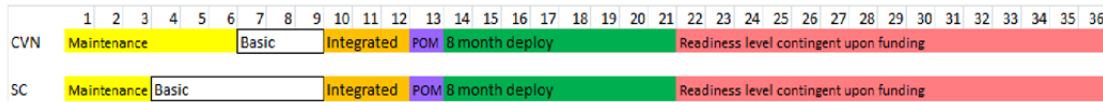
The following list is an excerpt from Admiral Howard’s OPNAVINST 3000.15A. By focusing the Navy’s resources and activities on these lines of effort, the OFRP will help generate the following:

- Predictable force generation cycles.
- OFRP cycle length that supports maintenance and training while maximizing employability.
- Consistent chain of command throughout OFRP.
- Right Sailor, right training, right time, in a sea-centric Navy.
- Continue rotational crewing and required manning at the beginning of the basic phase.
- Stable and predictable maintenance plan.
- Modernization that supports warfighting integration and interoperability.
- Parts, ordnance, and other transportation to support training and operations.
- Fully capable and modernized MSC ships available to support fleet combat and peacetime requirements.
- Consolidated and streamlined inspections, certifications, assessment, and visits.
- Forces trained to a single high-end, near peer standard.
- Tactical headquarters organization, capability, and capacity aligned with standardized maritime operations centers. (Howard 2014)

1. **OFRP Cycle**

The OFRP cycle is a 36-month cycle that begins in the maintenance phase. The maintenance phase is seven months long, followed by the basic and integrated, or advanced phase of seven months, and the sustainment and deployment phase of 22 months. Each phase is discussed in detail. The OFRP is illustrated graphically in Figure 11.

- **Retains ECP framework / capacity with reduced global Ao (~2.0)**
 - **36 month FRP**
 - **Single 8-month deployment**
 - **Starts with HST CSG in Nov 2014**



Adapted from Gortney (2014).

Figure 11. OFRP Cycle.

a. Maintenance Phase

Typically, the maintenance phase is a 24-week availability with a 4-week post-availability shakedown, but it can be as long as 16 months (Howard 2014). As delineated in Admiral Howard's OFRP, this phase focuses on major shipyard and depot-level repairs, upgrades, force reconstitution, and platform modernization. While performing maintenance, units must still focus on individual and team training in order to maintain a solid foundation of readiness (2014).

b. Basic Phase

The Basic Phase starts directly after a unit leaves the maintenance phase and typically lasts 6 months, though it can vary depending on the type of unit. According to the OPNAVINST 3000.15A:

The basic phase focuses on development of unit core capabilities and skills through the completion of basic-level inspections, certifications, assessments and visits and training requirements as well as achieving required levels of personnel, equipment, supply, and ordnance readiness. Units and staffs that have completed the basic phase are ready for more complex integrated or advanced training events, or appropriate tasking [such as homeland security or humanitarian assistance and disaster relief operations]. (Howard 2014)

Basic phase training focuses on a unit developing its core mission sets in preparation to move on to more advanced training that will require it to work with other units in an integrated environment such as within a CSG, ESG, air wing, or Surface Action Group.

c. Integrated Phase

“The purpose of integrated phase training is to synthesize individual units and staffs into aggregated, coordinated strike groups (or other combined-arms forces) in a challenging, multi-dimensional threat, realistic warfare environment” (Howard 2014). During this phase, units are given time to complete required inspections, certifications, and multi-unit training (both in port and out to sea) against high-end near-peer threat conditions (Howard 2014). Upon completion of this phase units will be certified to deploy and qualified to perform the following missions and capabilities at a minimum:

Proficiency in intelligence, surveillance, and reconnaissance, C2, air operations, maritime operations, information operations, power projection, ballistic missile defense, peacetime presence, amphibious operations, special operations forces support, combat search and rescue, mine warfare, sustainment and stability operations, and antiterrorism and force protection. (Howard 2014, 5)

d. Advanced Phase

The advanced phase is only for independent deploying forces that are not part of a CSG or ESG (2014). Like the integrated phase, this phase gives time to units to perform training, certification, and inspections. If these units are required to eventually aggregate into a CSG or ESG this phase can also provide integrated training, as necessary, as previously described. Once complete with this phase a unit will be certified to deploy (2014).

e. Sustainment Phase

The sustainment phase begins when a unit has completed basic or integrated training and ends when the unit returns to the maintenance phase (2014). During this phase, a unit can be deployed as a unit, multi-unit, or ESG/CSG in support of a combatant commander. During this phase, training aims to maintain a unit’s proficiency and readiness to deploy (2014).

2. Navy's OFRP Organization

As discussed earlier, the focus of the proposed WFTS is to develop a system that helps support basic, integrated, and sustainment training. To understand how the WFTS can do this, we need an understanding of the organization that supports these three phases. The following section examines the organizations (people, groups, units), the activities (tasks) they perform, and the operational items (information) that are passed between them.

a. Figure Guidance

In Figures 12 through 15, parallel lines represent the organizations involved in each phase of training. On each line, white boxes are used to represent activities (tasks) that each organization performs to support or provide training. The gray boxes show the inputs and outputs of information that operational activities share with other operational activities. Additionally, the figures also indicate a direction of flow. Parallel lines show that organizations are performing their set of operational activities congruently. The order of the operational activities shows that an organization may have to perform some activities before others. Finally, the arrows coming in and out of the grey boxes show what operational activities are producing and providing for other operational activities.

b. OFRP Illustrations

The following four figures provide an overview illustrating the complexity related to the conduct of sustainment, integrated, and basic training. These figures are not all inclusive of the detailed intricacies of the Navy's organization, but are useful in showing the general organizations involved, the activities they perform, and the information they share in the training environment.

As shown in Figure 12, operational activities or tasks of providing training in each of the basic, integrated, and sustainment phases of the OFRP are conducted in parallel. Each one of the three tasks is broken down into sub-tasks or sub-operational activities.

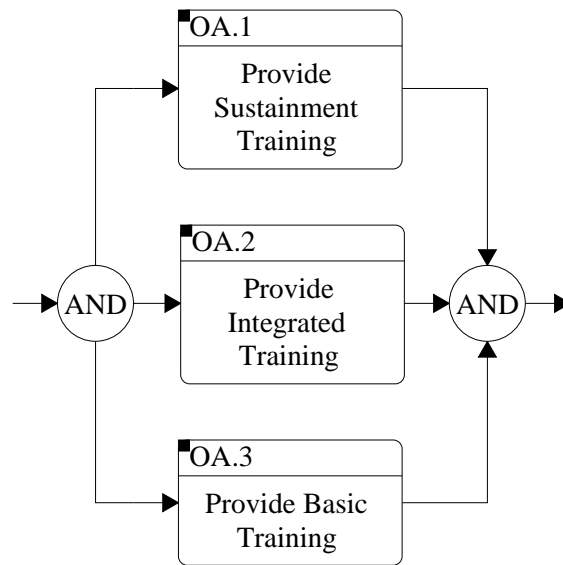


Figure 12. Operational Activity Overview

Figure 13 depicts the operational activities that the TYCOM, Certification Programs, Fleet Level Training Facilities, and CSG/ESG Units perform to facilitate training during the basic phase of the OFRP. The left side shows just the operational activities while the right side shows the inputs and outputs of the operational activities. For more details, see Appendix B, which lists the inputs and outputs of each operational activity along with the organization that performs that activity.

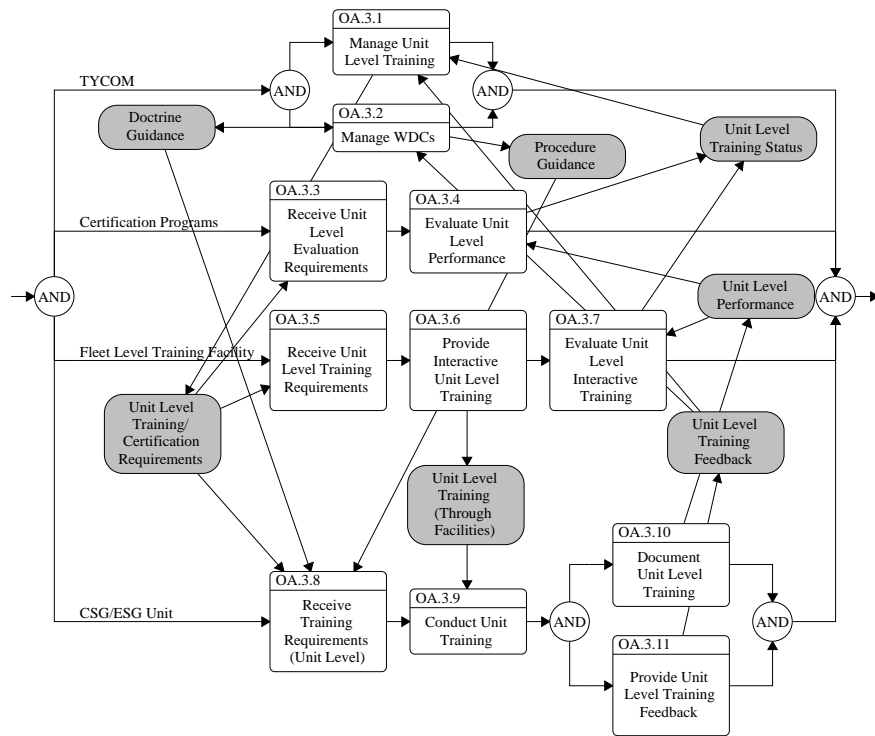
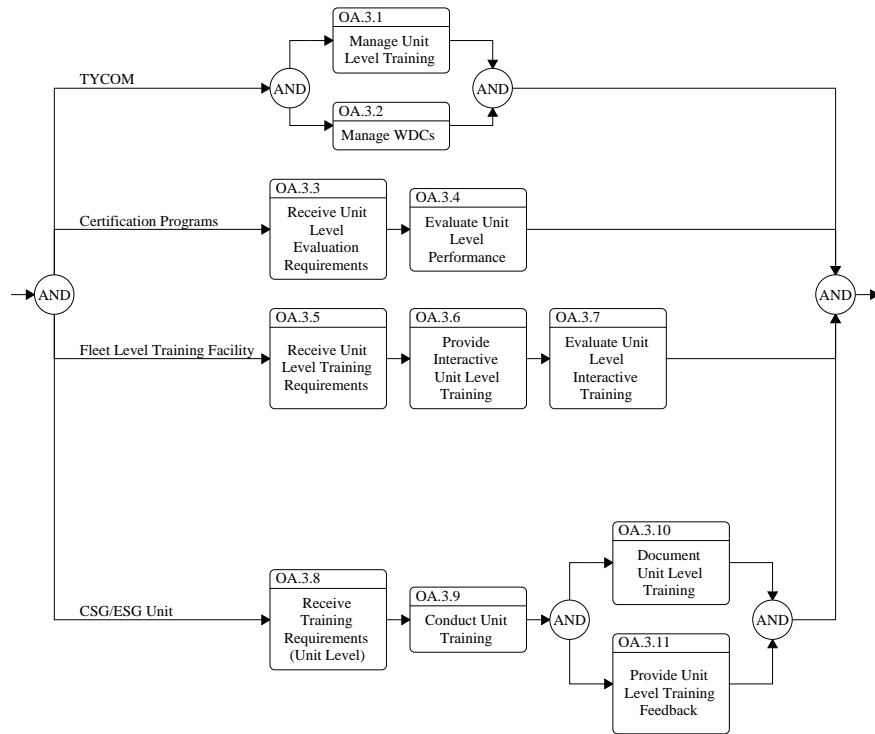


Figure 13. Basic Training Overview

Figure 14 depicts the operational activities that the Numbered Fleet Commander, Tactical Training Group, CSG/ESG Commander, Fleet Level Training Facilities, and CSG/ESG Units perform to facilitate training during the integrated phase of the OFRP. The left side shows just the operational activities while the right side shows the inputs and outputs of the operational activities. For more details, see Appendix B, which lists the inputs and outputs of each operational activity along with the organization that performs that activity.

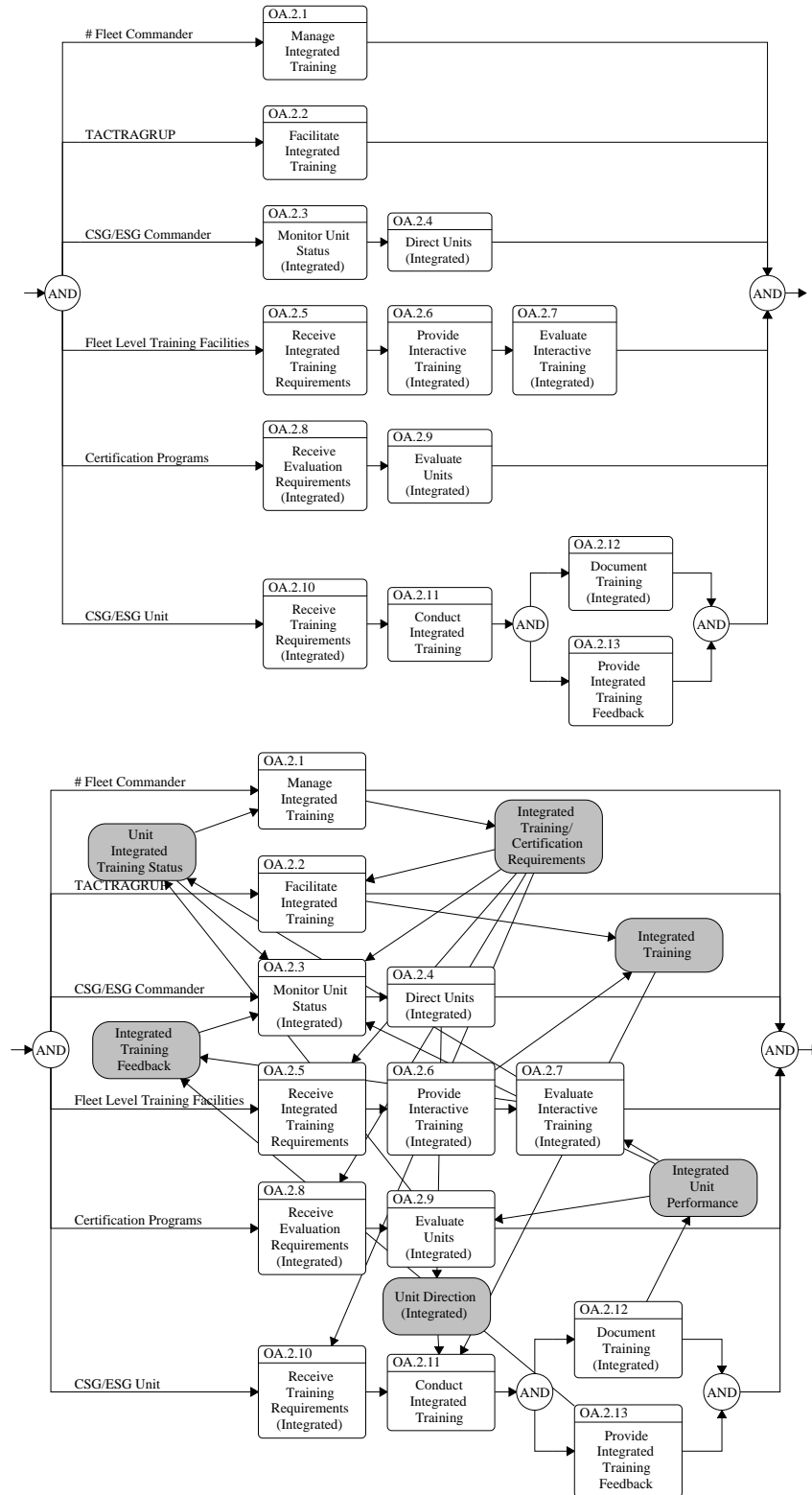


Figure 14. Integrated Training Overview

Figure 15 shows the operational activities that the Numbered Fleet Commander, CSG/ESG Commander, and CSG/ESG Units perform in order to facilitate training during the sustainment phase of the OFRP. The left side shows just the operational activities while the right side shows the inputs and outputs of the operational activities. For more details, see Appendix B, which lists the inputs and outputs of each operational activity along with the organization that performs that activity.

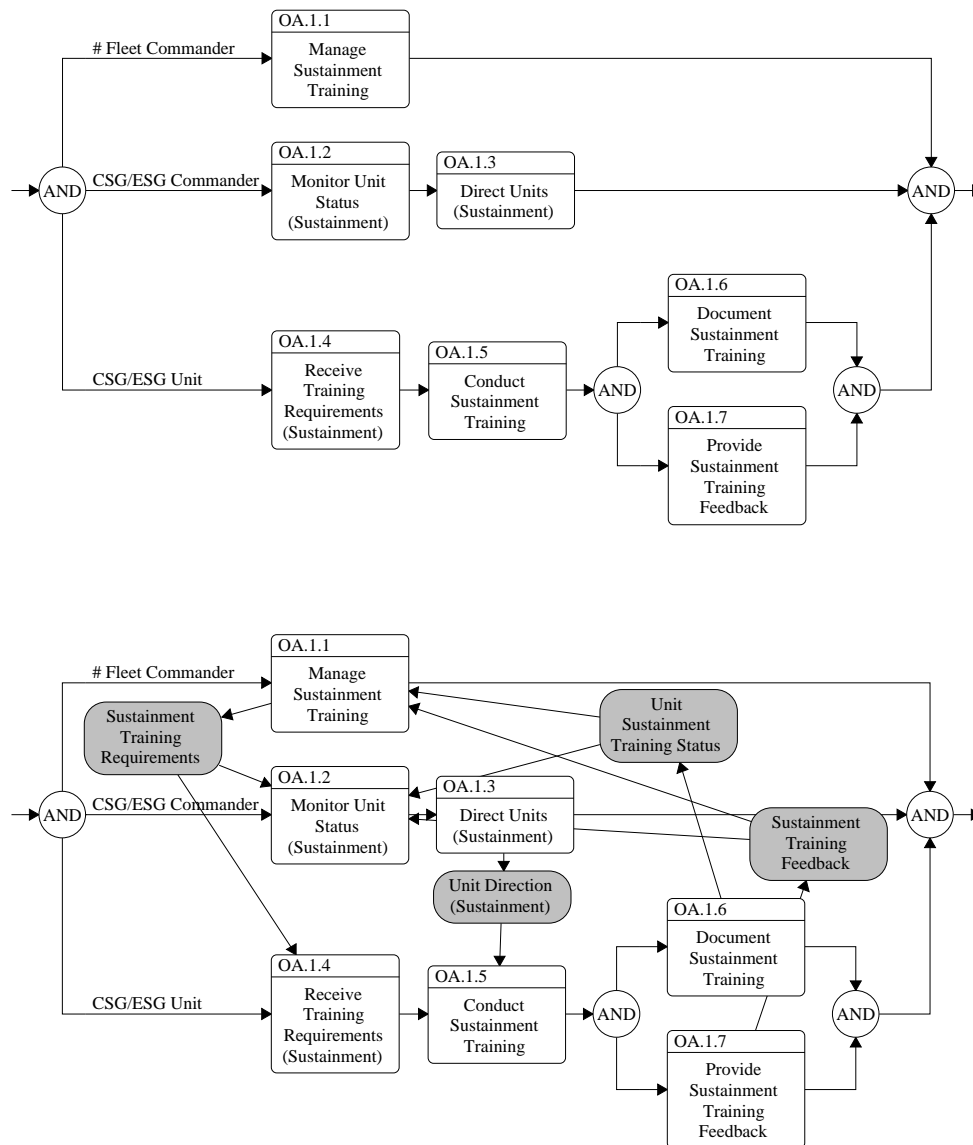


Figure 15. Sustainment Training Overview

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V. GAP ANALYSIS

Through research, interviews with stakeholders, and the development of a concept of operations for the WFTS, the team identified critical gaps in the Navy's training system that will prevent the future warfighter from effectively and efficiently employing webfires. Identification of these gaps is critical in the systems engineering process because any proposed solution must address known gaps. Systems engineers can use the identified gaps to help develop capability requirements that a system must possess in order "to meet an organization's role, functions, and missions in current or future operations" (Defense Acquisition University 2017). After capability gaps have been determined, the concept of operations (CONOPS) can be fully developed to describe how the future system will address these gaps. This CONOPS is useful to determine capability requirements that will then drive the rest of the system architecture that will be developed to address the defined gaps.

A. IDENTIFIED GAPS

"Gap Analysis is the comparison of actual performance with potential or desired performance; that is, the 'current state' the 'desired future state'" (Emery 2017). The following paragraphs discuss each gap in detail to explain how the current system struggles in meeting a gap and why the gap is important to webfires training. The team discovered four major gaps during our research. Some of the major gaps have multiple factors, which are expanded upon to provide background and an understanding of the nature of the gap.

1. Lack of Webfires Concept Training

The development of the webfires concept necessitates the development of a webfires training system. No other current training systems meet the unique requirements for a highly integrated warfare system. Limited elements of the needed training have been implemented, including NIFA-CA located in Fallon, NV; however, no overall centralized solution has thus far been developed.

2. Lack of Multi-Unit Training Repetition to Support Additional Webfires Training Requirements

The team considers the inability to perform quality repetitions as the most significant limitation to integrated training. Current training allocates limited time and resources during the integrated phase of training. While the traditional model is sufficient for today's battlespace, the webfires construct relies heavily on integrated tactics that must be practiced and improved upon. A significant increase in resources, including funding and time, would provide a measureable increase in overall CSG/ESG performance. A number of identified factors also hinder the ability to perform multiple iterations of integrated training. Following is a detailed list of factors that contribute to this gap and the training architecture will address.

a. Lack of Standardized Multi-Unit Scenarios for Training

The current approach to integrated training relies on third-party shore-based training groups, such as TACTRAGRUPAC/LANT, to provide pre-programmed scenarios for use in the integrated environment. These scenarios are difficult and expensive to produce and stage, and are unable to be performed independent of these third-party organizations. This hinders training multiple CSG/ESG. Additionally, the range at which the training can be conducted is reduced due to the line-of-sight limitations of these radio-operated networks. Providing the CSG/ESG the ability to create and run their own training scenarios that focus on the specific threats in an area of responsibility (AOR) can greatly improve training quality and relevance.

b. Lack of Communications Bandwidth between Ships and Simulators

Currently, integrated training relies heavily on using real communications circuits to conduct training. The issue with this approach is that communications circuits are limited in bandwidth and are often prioritized for military operations, thus limiting time and resources for effective training. Additionally, units must periodically conduct routine maintenance on their communications systems, which can limit a unit's capability to perform integrated training.

c. Lack of Resources at TTGs to Support Multiple Training Simulations Simultaneously

Currently integrated training relies heavily on a central node (TTGP/L) to establish communication and simulation links to perform a controlled scenario. This reduces the frequency of training events and limits the warfighter's ability to perform multiple repetitions to increase his or her proficiency. Increasing the physical data processing capability would not completely solve the issue. These facilities rely heavily on experts who are able to evaluate each unit's performance and provide useful feedback. The facilities also lack the number of qualified personnel who would be required to conduct more of this type of training.

3. Lack of Compatible Networks to Perform Multi-Unit Training

The severely convoluted and complex mix of network types and responsible parties that exists today is incompatible for the integration required to run the WFTS. The issue is rooted in two primary areas: the lack of common information assurance (IA) regulations across services and acquisitions programs, and the lack of a physical and reliable network system to connect live units and simulator stations.

a. Lack of Common IA Certifications to Integrate Data

Training networks are developed to operate for a specific purpose, which is generally focused on serving the community that acquired it. Often times, however, little thought has been placed into integrating these training networks. The attempt to integrate the Navy's training network with that of the Marine Corps is such an example. The major limitation is the lack of common IA certifications. The certifications designed to protect the data significantly hinder the ability to share data over different networks within the DOD. Other examples discovered during stakeholder interviews demonstrated that the ability to share data within the Navy's own networks is often artificially reduced through complex and non-standard IA requirements.

b. Lack of Ability to Interface Units and Facilities/Simulators

Current training facilities were designed only with their respective communities (i.e., helicopters, jets, destroyers, and cruisers) in mind, with little capability to interface with a different community. This obstacle is even more apparent in attempts to interface live units (i.e., deployed ships, flying aircraft) with simulators. Our research has shown very little capability exists to integrate these different training environments into a common scenario. To ensure the quality of training required to learn integrated tactics for employment of a webfires concept, these systems must be able to integrate seamlessly.

4. Lack of a Quality Feedback Process

At the end of any training event the students and instructors should gather together to replay the event and discuss the training in detail. Reviewing these details allows the students to recognize both the positive and negative decisions made and any possible future corrections. Conducting training without feedback detracts from the overall quality of training. Without the opportunity to review and correct mistakes in a timely manner, training quality and mission performance are negatively affected.

a. Lack of Face-to-Face Debriefing by SMEs and Groups Conducting Multi-Unit Training

The aviation community has recognized these benefits and adopted a robust feedback system. All involved pilots and instructors meet soon after each flight to review the training evolution. The use of available video and audio recording helps provide a clear picture of the events that took place. Additionally, instructors provide feedback directly to the students in an open forum to discuss any mistakes or confusion during the event. No one should walk away with any questions or confusion. This system, although beneficial, has not been adopted by all communities. However, the surface and sub-surface communities are beginning to implement various methods that attempt to model the aviation system with varying degrees of success.

b. Lack of Necessary Capability to Assess Webfires Training, Doctrine, and Procedures against a Near-Peer Threat

Current training systems contain functionality to assess the progress and effectiveness of unit-level training. These tools focus on providing detailed analysis for a single platform type. This limited analysis consequently isolates information required for integrated analysis. Determining the fleet's performance against future near-peer threats requires the ability to combine integrated performance results effectively to determine fleet tactical performance.

c. Lack of Automated Data Processing for Expedited Evaluation of Training

The current feedback process following a fleet exercise is painstakingly slow. Information processing times range from hours to weeks depending on the platform and event. The webfires training system must process results within an event timeline to produce desired training results effectively.

B. LESSONS LEARNED

To help identify the WFTS gaps, the team analyzed past and current training systems installed on ships and at training facilities to gain more insights. Based on these complex training systems, the team was able to identify some of the valuable lessons learned.

First, it takes a long time to properly design and install the training system onboard a ship. This is due to several reasons. One reason is that procedures are difficult to follow and complete properly. The other reason is the sailor's lack of training in installing the equipment. Second, it takes a long time to troubleshoot the training systems. Due to the complex nature of the training system hardware and software, the maintainers must spend considerable time troubleshooting and repairing the systems. Third, there is lack of interfaces between training facilities. Various contractors have designed and built the training systems, often making these systems unable to communicate with each other for an integrated training event. Finally, there are many connectivity issues between ships

and training facilities. This is due to both the poor reliability of pier connections and a ship's scarcity of bandwidth.

VI. CONCEPT OF OPERATIONS

This chapter describes the process by which the proposed WFTS will operate. After defining the process, the chapter presents short illustrative stories to help the reader put the operations into context.

A. DEFINITION

According to the website, AcqNotes.com (2017d), a resource archive for acquisitions and engineering professionals working in the DOD environment, a CONOPS is defined as:

CONOPS is used to examine current and new and/or proposed capabilities required to solve a current or emerging problem. It describes how a system will be used from the viewpoints of its various stakeholders. This provides a bridge between the often vague capabilities that a project begins with and the specific technical requirements needed to make it successful. A CONOPS is a useful tool that helps the user community write/refine [capability requirements and functional requirements that a system must have in order to close the identified capability gaps and meet the intended goals of a system].

In conjunction with vignettes (short stories describing the system solving the problem), the CONOPS helps designers develop final capability requirements, system requirements, operational activities, and functions that the system must perform in order to fill the capability gaps that were previously identified. Once these steps have been completed, an analysis of alternatives is conducted to determine the solution that will best fulfill the requirements and address the capability gaps. From the AcqNotes website, the purpose and objectives of a CONOPS are summarized below.

1. Purpose

- Aid in getting stakeholder agreement on how the system will be operated.
- Help show high-level system concepts and aid in their justifications.
- Help define high-level requirements.
- Define the environment in which the system will operate.

- Help in the system validation process.

2. Objectives

- The goals and objectives of the system.
- Constraints affecting the system.
- Organizations and interactions among participants.

This chapter begins by introducing the CONOPS and presenting the Operational View-One (OV-1) for the proposed training system. It then presents multiple vignettes that explore common scenarios detailing how the WFTS will operate. These vignettes illustrate how webfires will enhance in-port, underway, unit, and multi-unit training during the basic, integrated, advanced, and sustainment phases of the OFRP.

B. WFTS CONOPS

As shown in Table 7, by using technology such as actual and simulated communication links, augmented reality, hi-fidelity simulators, and actual combat systems in each phase of the OFRP, the scenarios performed in-port and underway will enable improved single unit and multi-unit training.

Table 7. Types and Phases of Webfires Training

| Types of Training | | OF RP PHASE | | |
|-------------------|----------|-------------|------------|-------------|
| | | Basic | Integrated | Sustainment |
| Unit | In-Port | X | X | X |
| | Underway | X | X | X |
| Multi-Unit | In-Port | N/A | X | X |
| | Underway | N/A | X | X |

Looking at Figure 16, we see that as units conduct training and data is collected it can be used to aid organizations in evaluating and certifying units for the next phase of the OFRP. Additionally, that data is useful for evaluating the effectiveness of training, doctrine, and procedures that are developed for near-peer threats.

If training, procedural, or doctrinal gaps are discovered, they can be corrected and delivered to the fleet in a timely manner. Additionally, this figure shows that SMEs associated with near-peer threat doctrine and procedures can help create and manage the scenarios that are used to train the fleet.



Images from Navy.mil, GlobalSecurity.org, USFFC, NAVAIR, NAVSEA, SPAWAR, NWDC, ONI, CAE, IBM, and SECNAV.

Figure 16. WFTS CONOPS Diagram

C. VIGNETTES

A vignette is a brief description that is used to describe how a system will operate once it has been fully implemented. These descriptions are useful in the engineering process because they can aid engineers in placing system functions, requirements, and capability gaps in context. Using vignettes engineers can creatively analyze the capability gaps and explore ways that a system might close those gaps.

This portion of the report uses illustrative descriptions to show how the future WFTS can provide both unit and multi-unit training while CSG units are in-port or

underway during the basic, integrated, and sustainment phases of the OFRP. Although these vignettes are useful in identifying future capabilities, they may not be representative of the final capabilities that the future system will have.

1. In-Port Unit Training

A ship has just completed the maintenance phase of the OFRP and needs to prepare its crew to deploy with a CSG. Proficiency and currency are low and the crew needs to gain experience rapidly in order to move forward to integrated training with the CSG.

While in port, the ship's crew takes turns running simple preprogrammed scenarios on their shipboard systems that were developed by SMEs knowledgeable about enemy tactics and procedures. The goal of this training is to help familiarize watch standers with their consoles and equipment, and reinforce current doctrine, procedure, and tactics to which they should have been trained. Data is collected that allows the commanding officer and higher organizations to evaluate the crew's performance and to determine the effectiveness of the training. This allows organizations to track whether a ship or unit needs special training to aid in preparing for the next phase of the OFRP. This data could also be used to certify a unit is ready to proceed to the integrated phase of the OFRP. During this phase of training, if a ship is unable to conduct onboard training due to maintenance actions it will be able to send watch standers to a shore facility where the same scenarios can be run on simulated shipboard equipment.

2. Underway Unit Training

While preprogrammed scenarios are useful in helping to train units, actual training at sea can greatly increase the training value by interjecting real world events, such as weather and connectivity issues, in communication systems. Adding the extra dimension of realism allows watch standers to receive more realistic training and better prepare them for a near-peer threat. Simulation adds value in training but reliance on too much simulation in the future can also be a disadvantage.

During this type of training, a ship can run preprogrammed scenarios that simulate real contacts through augmented reality. For instance, a ship can practice maneuvering to track and then attack a simulated submerged threat. As previously mentioned, data will be recorded to allow the ship and other organizations to evaluate performance and help certify the unit is ready to proceed to the integrated phase of the OFRP. Additionally, more advanced simulations can be produced to simulate friendly ships and aircraft to aid individual units in aspects of training that will be required for the integrated and sustainment phases of the OFRP.

3. Multi-Unit Training During the Integrated Phase

While in port, any combination of multiple ships, aircraft simulators, and ship simulators can connect to a network that will allow them to simulate the real world communications necessary to employ webfires as well as allow them to simulate a shared scenario. This simulation can be a preprogrammed scenario during the beginning of the integration phase, or it can consist of highly choreographed scenarios managed by a training organization during later phases of the integration and sustainment phases.

All of the friendly units are played by the actual units that will be deploying together as a CSG or ESG. The location of each of those units is simulated as underway in the area in which they will be deploying. Expected opposition forces are developed, simulated, and controlled by SMEs at the relevant tactical training groups to provide high-fidelity enemy actions and responses during the more advanced stages of the integrated phase. Despite the geographical separation between the participants, some out to sea, some in port, and some unable to use their own ship's systems due to equipment casualties, the entire strike group is able to integrate into a common operating picture to conduct integrated training.

Like single-unit training, data from multi-unit training can be recorded and used by organizations to help evaluate and certify units to continue into the next phase of the OFRP or for deployment. Additionally, during these advanced threat scenarios, data can be recorded to evaluate the effectiveness of current doctrine, procedure, and tactics

employed by the fleet. If discrepancies are found, or more efficient means of prosecuting a target are discovered, the TTPs can be updated accordingly.

4. Underway Sustainment Phase Training

During this type of training, each unit can carry equipment (permanently installed or temporary) that will allow the unit to form and utilize a webfires network. For this exercise, each unit has put its system in training mode, allowing the unit to send and receive simulated combat data, shared by a common network seen by all. The servers needed to run the simulation software will be primarily housed on the aircraft carrier at the heart of the strike group. Other surface units have server racks that can help process and relay webfires data on a smaller scale in the carrier's absence.

With the simulation processing capability resident to the strike group, no connection back to the training centers on land is needed. SMEs embedded in the strike group in the form of Weapons and Tactics Instructors control the opposition forces and provide a sense of realism to enemy actions. Only the enemies and the weapons are simulated. For example, real fighters fly against computer-simulated aircraft, and ships execute real maneuvers against simulated submarine threats. Real communications and real console operations take place in training mode. For most console operators, there should be no appreciable difference between the simulated combat scenario on their consoles and what would appear on the consoles during actual combat.

VII. SYSTEM REQUIREMENTS

After determining the capability gaps and the concept of operations of the new system, the next step in the systems engineering process is to identify the requirements that the system must fulfill in order to bridge those gaps while meeting the goals of the CONOPS. Requirements form the basis of the future system design. All functions and operational activities that a system possesses must fulfill all the stated requirements. Those functions and operational activities can then be used to assign tasks to operational nodes and components to meet system functions. For the purpose of this report, there are two basic types of requirements: capability requirements and functional requirements. These are described in detail in the following sections.

A. CAPABILITY REQUIREMENTS

A capability requirement (also known as an operational requirement) is a requirement delineating a capability that a system must have in order to meet the missions of a system (Defense Acquisition University 2017). Capability requirements directly relate to the CONOPS and how the future system will be employed to provide training and address the capability gaps identified in Chapter V.

These capability requirements are a driving factor in the system architecture for the WFTS because capabilities are addressed by tasks that the system must accomplish. These tasks are then implemented by system functions, which are performed by system components.

If capability requirements are not fully developed, it is possible that a system is built that does not adequately perform the missions of that system. Using capability gaps and the CONOPS developed earlier, the following capability requirements were developed. Each requirement is described in detail as this section maps the capability requirements to the capability gap(s) that it addresses.

1. Training Requirements

These are requirements that directly focus on training the warfighter. These requirements focus on when, where, and how a warfighter and unit can train.

a. The System Shall Integrate Webfires Concept Training during the Basic, Integrated, and Sustainment Phases of the OFRP

By integrating the WFTS into the basic, integrated, and sustainment phases of the OFRP, units can train on webfires concepts throughout their entire training cycle prior to deployment and maintain their proficiency to use webfires after deployment. By introducing elements of webfires training into the OFRP cycle during the basic phase, units will progress through the integrated phase with greater proficiency and will then be more capable to fight a near-peer threat while on deployment or during the remainder of the sustainment phase. This will introduce integrated training in the basic phase through simulation.

b. The System Shall Integrate Webfires Concept Training during Unit and Multi-Unit Training

The nature of the webfires concept is to integrate units together to process a target. The integration of this training during unit and multi-unit training exercises will better prepare units to work together to defeat a near-peer threat. Integrating webfires concept training into unit training exercises will allow individual units to focus on specific training deficiencies that need improvement prior to conducting multi-unit training.

c. The System Shall Integrate Webfires Concept Training In-port and Out-to-Sea

By integrating webfires training with units in port and at sea, units will better be able to practice the skills necessary to perform webfires, regardless of location or underway schedules.

2. Repetition Requirements

These requirements focus on increasing the number of repetitions that warfighters can do with respect to training. Repetitive high quality training will help increase retention of skills and knowledge.

a. The System Shall Provide Standardized Training Scenarios for Unit and Multi-Unit Training

Standardized scenarios enable units to have a set of standards by which they can be trained to fight a near-peer threat. This will also allow units to train to quality scenarios that are provided by SMEs on the enemy and the tactics that they employ. By using these standardized scenarios, units will not have to create their own and will be able to perform quality training with greater frequency.

b. The System Shall Provide Training with Limited Communications

By providing training in limited communications environments or in port, units will not have to rely heavily on real communications circuits or outside entities to provide communications. Thus, units will be able to perform more training.

c. The System Shall Be Capable of Allowing Units/Simulators to Independently Establish Training Simulations with Other Units

By allowing units or simulators to run simulations or scenarios with other units, multiple units can train independently from one another during all phases of the OFRP. This will allow units to practice integrated operations earlier in work-ups and prior to deployment, and will increase the quality of the training. Additionally, this means that units will not have to rely on some other entity to establish a training scenario for them and will allow multiple units to perform multiple multi-unit scenarios at the same time.

d. The System Shall Integrate with and Be Capable of Integrating with Current and Future Strike Group Units, Networks, and Training Facilities/Simulators

This will allow units to conduct training using their own systems instead of relying on simulators that may not be the actual equipment that sailors will use in combat.

Furthermore, this capability should allow simulator facilities to link up and conduct exercises with actual units. This will increase the quality of the training and allow for training to be done more frequently in port and at sea.

3. Feedback Requirements

These requirements focus on feedback that can aid high-velocity learning. Repetition is useful; however, if warfighters are not training correctly or more effectively then the value of that repeated training is less productive.

a. The System Shall Provide Data that Can Be Used to Assess Effectiveness of Training, Doctrine, and Procedures against a Near-Peer Threat

By providing this data, warfare experts can evaluate the effectiveness of the training and determine whether units need more attention to better prepare them for deployment. Additionally, this data is useful for informing the developers of tactics, doctrine, and procedures about the effectiveness of these elements against a simulated near-peer threat, allowing the TTPs to be updated as necessary.

b. The System Shall Provide Data that Can Be Used to Evaluate and Certify Units during the OFRP Cycle

The system can provide data that is useful to certify units, and this can reduce the time and separate certification requirements that units must meet in order to advance to the next phase of training.

4. Summarized Capability Gaps

For the reader's benefit in correlating the requirements and gaps, the following list summarizes the capabilities gaps that were identified in Chapter V.

1. Lack of Webfires Concept Training
2. Lack of Multi-Unit Training Repetition to Support Additional Webfires Training Requirements
 - a. Lack of Standardized Multi-Unit Scenarios for Training

- b. Lack of Communications Bandwidth between Ships and Simulators
 - c. Lack of Resources at TACTRAGRUPAC/LANT to Support Multiple Training Simulations Simultaneously
- 3. Lack of Compatible Networks to Perform Multi-Unit Training
 - a. Lack of Common IA Certifications to Integrate Data
 - b. Lack of Ability to Interface Units and Facilities/Simulators
- 4. Lack of a Quality Feedback Process
 - a. Lack of Face-to-Face Debriefing by SMEs and Groups Conducting Multi-Unit Training
 - b. Lack of Necessary Capability to Assess Webfires Training, Doctrine, and Procedures against a Near-Peer Threat
 - c. Lack of Automated Data Processing for Expedited Evaluation of Training

The mapping (traceability) of each capability requirement to a corresponding gap is shown in Table 8. By mapping the capability requirements to the capability gaps, the systems engineer introduces traceability and can ensure that the new system is addressing the identified capability gaps. Failure to ensure that each capability gap identified is being addressed would result in a system that fails to meet the needs of the stakeholders.

The WFTS as envisioned in this report is unable to address capability gaps 3a and 4a at this time. After thorough discussion, the team determined that these specific gaps are outside the scope of this report and will be recommended as future research topics.

Table 8. Mapping Capability Requirements to Capability Gaps

| <u>Capability Gap</u> | <u>Capability Requirement</u> | <u>Discussion</u> |
|-----------------------|-------------------------------|--|
| 1 | 1a–1c | A system designed to integrate webfires into unit and multi-unit training while at sea or in port during the basic, integrated, and sustainment training phases of the OFRP will address the gap of no current webfires concept training currently exists. |
| 2a | 2a | Preprogrammed scenarios will address the gap of no preprogrammed scenarios. |
| 2b | 2b | The ability to train with limited communications will address the lack of communications bandwidth between ships and simulators. |
| 2c | 2c | The capability of units/simulators to establish their own scenarios will address the gap of having to rely on the limited resources of TACTRAGRUPAC/LANT. |
| 3a | N/A | The WFTS will not address this capability gap. |
| 3b | 3 | The WFTS' capability to integrate with all units/simulators will address the gap of lacking the ability to interface units and simulators. |
| 4a | N/A | The WFTS will not address this capability gap. |
| 4b | 4a | Data provided by the new training system will fill gap of the current training system in providing the capability to assess training, doctrine, tactics, and procedures. |
| 4c | 4b | Data provided by the new system will allow for faster evaluation and certification of training. |

B. FUNCTIONAL REQUIREMENTS

“A functional requirement is simply a task (sometimes called an action or activity) that must be accomplished to provide an operational capability (or satisfy an operational requirement)” (AcqNotes 2017c). These functional requirements used to determine the functions that the components (hardware and software) of the system must perform in order to satisfy the capability requirements and close the gaps that were identified.

Functional requirements are derived from capability requirements and are used to help develop system functions. Later in the systems engineering process, these functions

help to identify design alternatives and conduct an analysis of alternatives. The functional requirements identified for the WFTS include:

1. The system shall be able to integrate with all CSG/ESG units' weapons systems capable of conducting webfires.
2. The system shall be able to interface with current and future webfires capable training facilities and simulators.
3. The system shall be able to receive updates from the intelligence community of current enemy's threats.
4. The system shall be compatible with existing networks and ship systems.
5. The system shall be able to provide standardized preprogrammed simulations to the warfighters.
6. The system shall provide the ability for units to modify preprogrammed simulations.
7. The system shall provide the ability for units to create simulations.
8. The system shall provide the ability for multiple units and training facilities to conduct the same integrated training scenarios simultaneously.
9. The system shall support multiple simulations running concurrently.
10. The system shall support the simulations being controlled by units, simulators, or commanders.
11. The system will support the storage of simulations in a simulation bank.
12. The system shall collect and provide data that can be used to evaluate the performance of the training system.
13. The system shall collect and provide data that can be used to certify and evaluate units.
14. The system shall use communication circuits available in 2025–2030.

C. REQUIREMENTS SUMMARY

This chapter discussed the capability requirements and functional requirements that the webfires concept must possess in order to fill the capability gaps. The capability requirements were then used to determine functional requirements that will help the system meet the capability requirements. Both the functional requirements and capability

requirements will be used to determine the operational activities (people/organizational functions) that the system must have and the system functions (hardware/software) that the system must possess to fulfill these capability requirements and functional requirements. These operational activities and system functions also help identify possible design alternatives that are discussed later in more detail in Chapter IX.

VIII. FUNCTIONAL ANALYSIS

A. FUNCTIONAL ANALYSIS

Functional analysis is a critical step in the systems engineering process. This analysis is performed in the conceptual design phase of any project that seeks to translate top-level system requirements into meaningful design criteria (Blanchard and Fabrycky 2011, 86): “A function refers to a specific or discrete action (or series of actions) that is necessary to achieve a given objective [and] may ultimately be accomplished through the use of equipment, software, people, facilities, data, or various combinations thereof” (86).

[F]unctional analysis is an iterative process of translating system requirements into detailed design criteria and the subsequent identification of the resources required for system operation and support. It includes breaking requirements at the system level down to the subsystem, and as far down the hierarchical structure as necessary to identify input design criteria and/or constraints for the various elements of the system. The purpose is to develop the top-level system architecture, which deals with both “requirements” and “structure.” (Blanchard and Fabrycky 2011, 86)

Using tools such as functional decompositions and functional flow block diagrams, engineers can determine the functions that a system must have in order to meet system requirements. This ensures that all requirements are being met by the system; it is imperative that engineers verify that system requirements are traceable to each of the established system functions.

B. SYSTEM FUNCTIONS

Within the architecture for the WFTS, the team determined that there were numerous functions that must be accomplished in order to meet the requirements laid out in Chapter VII. These primary functions are depicted in Figure 17.

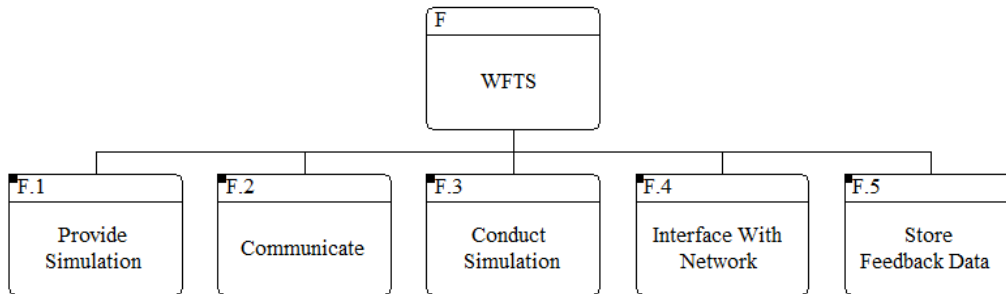


Figure 17. WFTS Primary Functions

Furthermore, within each primary function, various sub-functions are needed to achieve the overall goal of the WFTS. To facilitate the hierarchy between these sub-functions, a functional decomposition structure is created for each primary function.

1. Provide Simulation

Within the Provide Simulation function of the WFTS, the first level hierarchy is shown in Figure 18.

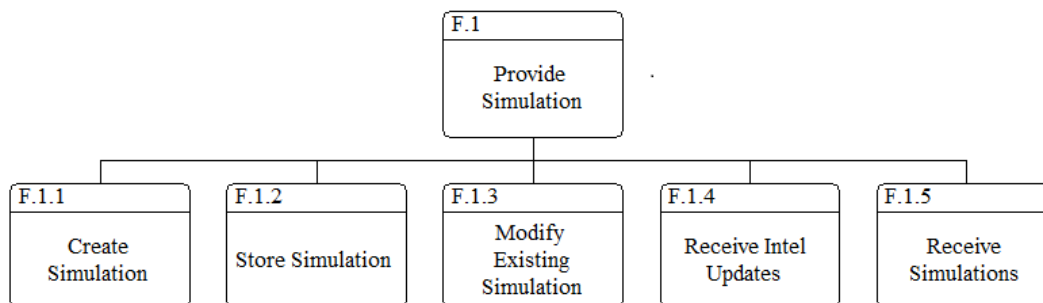


Figure 18. Provide Simulation Functional Hierarchy

a. Receive and Store Simulations

As a basis for training, especially with consideration to high-velocity learning, the WFTS must be able to receive and store simulations as published by the designated training leader during all stages of the OFRP. At the heart of multi-domain training is a common goal to be achieved for a given state. Based on what training simulation would be needed or expected to prepare warfighters for their deployment to various AORs,

simulations would be given to all participating units from the theater commander. Correspondingly, each unit would need to store and readily obtain a training scenario from a WFTS simulation database.

b. Create and Modify Simulations

The WFTS must be able to quickly adapt to changing tactics, differing missions, geopolitical limitations, regulatory changes, etc. With such a plethora of variables that could potentially impact any number of missions, the training scenarios must be tailorable to mimic conditions that are to be expected throughout the world in varying theaters. Commanders will need to be able to either create a simulation from scratch, or be able to change any variables (referred to as “technical injects”) prior to enacting a simulation. Potential changes to force levels, maneuverability restrictions, battle damage, participating units, etc., will affect the fidelity of the training. Additionally, intelligence updates must be programmable into the simulations.

c. Receive Intel Updates

Actively inviting intelligence agencies’ inputs regarding potential enemy tactics and weapons would enhance the fidelity of scenarios—especially the simulation of these near-peer red forces in a cross-domain campaign simulation. Intelligence update data must be programmed into the system as expeditiously as possible.

2. Communicate

At the most basic level, the communication structure of the WFTS must maintain the ability for data and voice communications to reach the warfighters reliably and effectively. This must occur prior, during, and after any simulation or scenario is run on the variety of platforms with which the system will interact. These networks must be able to operate completely independently no matter where the units or simulators are physically located (i.e., in port or underway). A hierarchy of this function is shown in Figure 19.

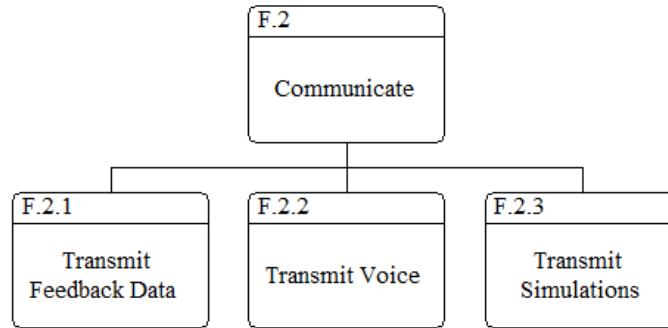


Figure 19. Communicate Functional Hierarchy

a. *Transmit Data/Voice/Simulations*

In the 2025–2030 timeframe for which the WFTS is designed, networks are assumed to be established for cross-domain communications. These various wired and wireless networks shall provide the means to transmit data (for both the simulations themselves and the information gathered after running them) and voice signals before, during, and after scenarios.

3. Conduct Simulation

Each time the WFTS runs a simulation or scenario, it must be controlled by either human operators or artificial intelligence algorithms. This control will not only be within the organization that has cognizant control over the conduct of all the players, but also within the equipment and simulators that are used. The functional hierarchy for this is shown in Figure 20.

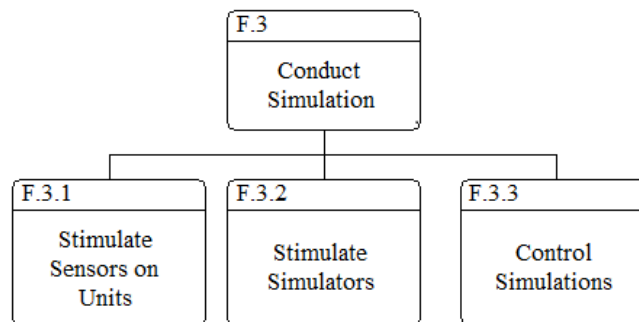


Figure 20. Conduct Simulation Functional Hierarchy

a. Control Simulations

At any time, a participant unit in a scenario will perform tasks based on parameters such as previous training, human factors, and available information. The scenario lead must establish the beginning, end, and desired pauses while the scenario is running. Therefore, the system must allow the assigned lead to maintain control. In addition, simulation modifications, such as technical injects, may occur after a scenario has been initiated. The lead must be able to control what information changes in real time to allow for more realistic and effective training.

b. Stimulate Sensors Onboard Units and Simulators

With the linking of units to simulators during a WFTS scenario, maximum fidelity and learning will occur if the warfighter is able to see what he or she would see in an actual event. Therefore, it is paramount to ensure that equipment, both within the simulator tool and aboard actual ships, reacts properly: giving actual displays that correspond to what should be expected in a combat environment.

4. Interface with Network

The network that provides the backbone for the WFTS' operation must accomplish two main interface functions—interaction with the human end-users of the system and interaction of system components in an information technology infrastructure. Figure 21 depicts this hierarchy, which is expanded in the following discussion.

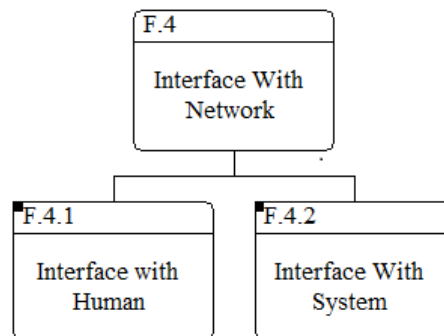


Figure 21. Interface with Network Functional Hierarchy

a. *Interface with Human*

The WFTS will utilize the latest technology for relaying information as quickly as possible. This information will include such data as the effect of the unit's actions, probability of kill, and other vital tactical information. The graphical display will be designed to mimic what information would be provided during an actual engagement. Additionally, displays for the scenario lead or training commander will allow for immediate feedback regarding individual unit effectiveness and level of preparedness for each unit's corresponding OFRP phase. These functions are shown in Figure 22.

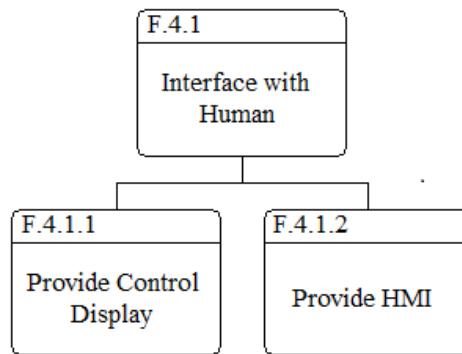


Figure 22. Interface with Human Functional Hierarchy

As a complement to activation of shipboard equipment during a unit-to-unit or simulator-to-unit scenario, WFTS will interact with warfighters via sensors or indications on equipment that they are familiar with, to enhance tactical effectiveness.

b. *Interface with System*

WFTS has an extensive relationship between the various systems aboard a unit and at simulation facilities. This is where the major benefits of the systems can truly be realized to accomplish commander's intent. The interactions include links from:

- Unit-to-unit: i.e., watch standers on surface ships, airborne units, and a submarine bridge-team
- Unit-to-simulator: i.e., USMC pilots in shore-based simulator, and submarine bridge-team

- Simulator-to-simulator: i.e., Surface Officer Warfare School simulator and P-3 simulator

Information will travel via the aforementioned communication networks to achieve these connections. These functions are depicted in Figure 23.

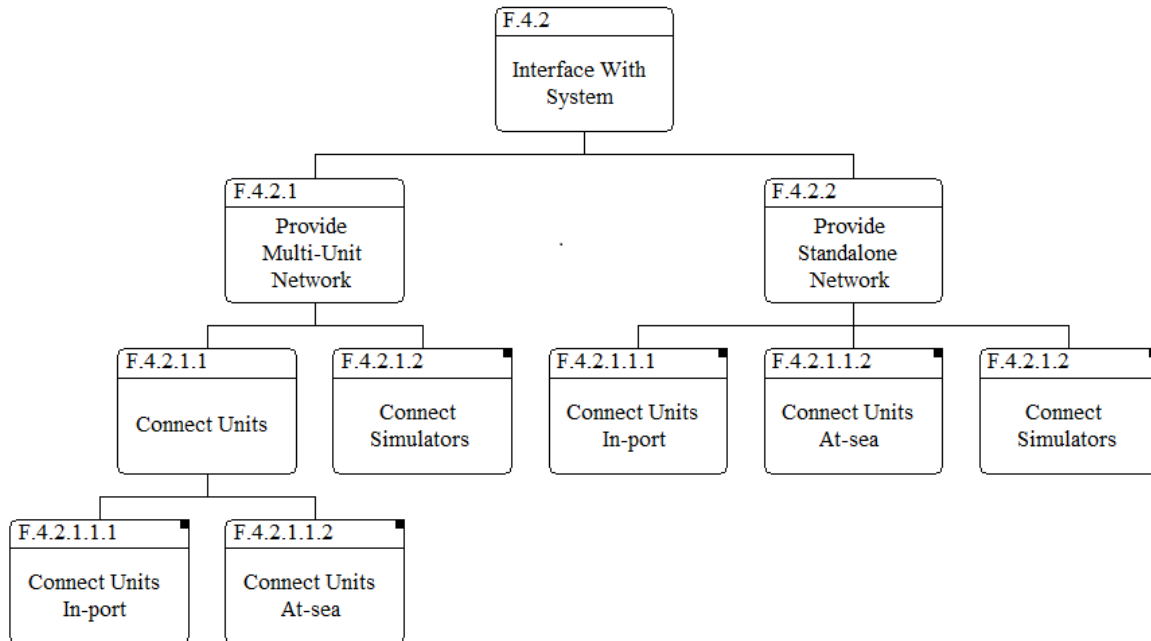


Figure 23. Interface with System Secondary Functional Hierarchy

(1) Provide Multi-Unit Network

The network simulations will be run by units or in simulators. The latter representing a shore-based, established training facility. The units can either be networked in port, via shore command, control, and communication (C3) facilities, or by at sea C3 networks.

(2) Provide Standalone Network

Due to the limited bandwidth potential or threat of operating in a denied/degraded environment, WFTS simulations must be able to operate via standalone systems. Each unit will need the ability to execute required training without dependence on traditional at-sea or in-port connections. Infrastructure will include digital media able to record

results during standalone simulations, as well as an ability to upload feedback data once a network is available.

5. Store Feedback Data

In addition to providing information instantaneously to participants, the feedback must be stored for playback and analysis during the debrief. This can aid in improving future training (i.e., best/worst practices) and individual unit performance metrics. In this manner, decision making among WFTS participants during a simulation can contribute to future modifications of TTPs for use in a webfires construct. A breakdown of functions is shown in Figure 24.

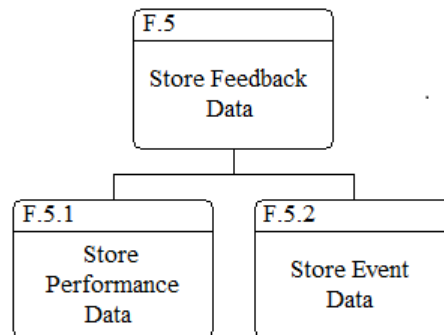


Figure 24. Store Feedback Data Functional Hierarchy

C. OPERATIONAL ACTIVITIES

After defining and decomposing the functions of an optimally designed WFTS, it is then important to understand how the new system will accomplish the unique operational requirements of stakeholders. By taking a higher, overarching view of the system and then further breaking down activities that will be performed, the systems engineer can identify the roles that can be assigned to units and supervised by cognizant commands.

Described in detail later in this report, the primary way to demonstrate operational activity relationships in DOD programs is to utilize DoDAF diagrams. One of these diagrams, the Operational Activity Decomposition Tree (OV-5a) will show the iterative

nature of operational activities that accomplish the functions listed previously in this chapter. Based on the OV-5a, Figure 25 depicts the relationship between the WFTS and the activities that need to be performed by the system.

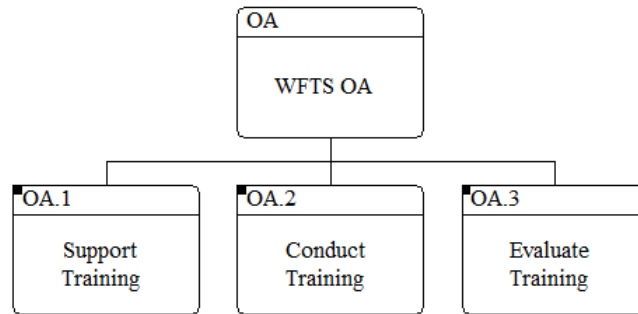


Figure 25. Overall WFTS Operational Activities

1. Support Training

To support training on a webfires network, additional operational activities will be accomplished as shown in Figure 26.

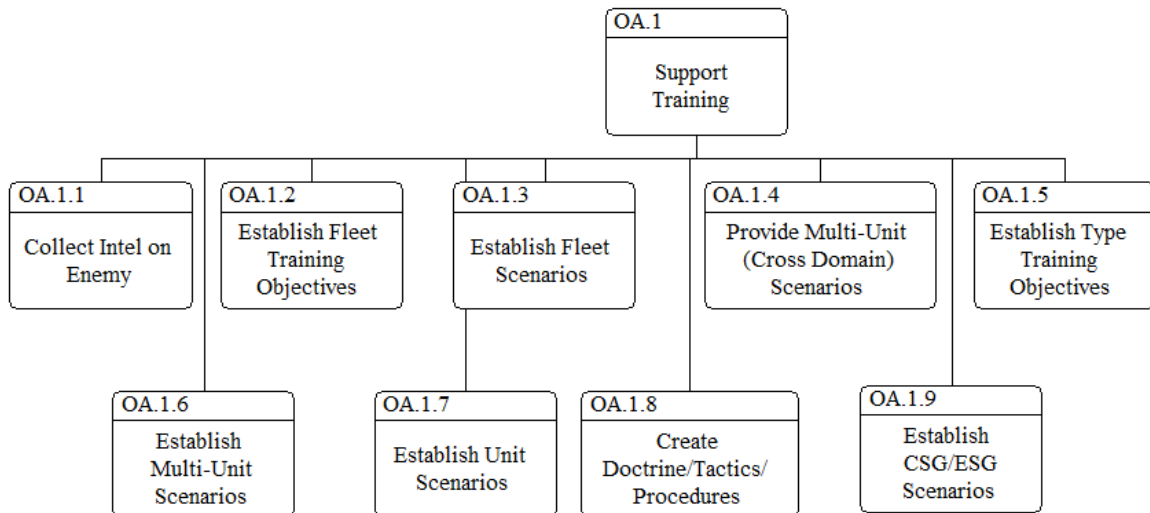


Figure 26. Support Training Operational Activity Hierarchy

a. Collect Intelligence on Enemy

Within the purview of a webfires network, warfighters must know what to expect from adversary units. The intelligence inputs to the WFTS allow for a simulated near-peer threat to display real-time tactics and capabilities for more realistic learning and contributing to a high-velocity learning concept.

b. Establish Training Objectives

In order to evaluate the training process (described later in this chapter), the objectives of the fleet-wide usage of the WFTS must be established and changed as necessary to match the commander's intent. This occurs at the fleet (geographic) and type (platform) command levels.

c. Establish Scenarios

At multiple command levels and during each phase of the OFRP, scenarios will be established to match what their respective units will expect to encounter in an AOR. This occurs at the fleet (geographic), CSG/ESG (strike group), unit (individual vessel), and multi-unit (interoperation between vessels exclusive of the strike group), and cross-domain (interoperation encompassing all potential fleet and platform) levels.

d. Create Doctrine/Tactics/Procedures

Based on feedback garnered from WFTS events, modifications will be implemented to simulation protocols based upon warfighter actions and enemy tactics for optimization of offensive and defensive actions in an operational webfires environment.

2. Conduct Training

In order to conduct training to implement a webfires network, additional operational activities will be accomplished as shown in Figure 27.

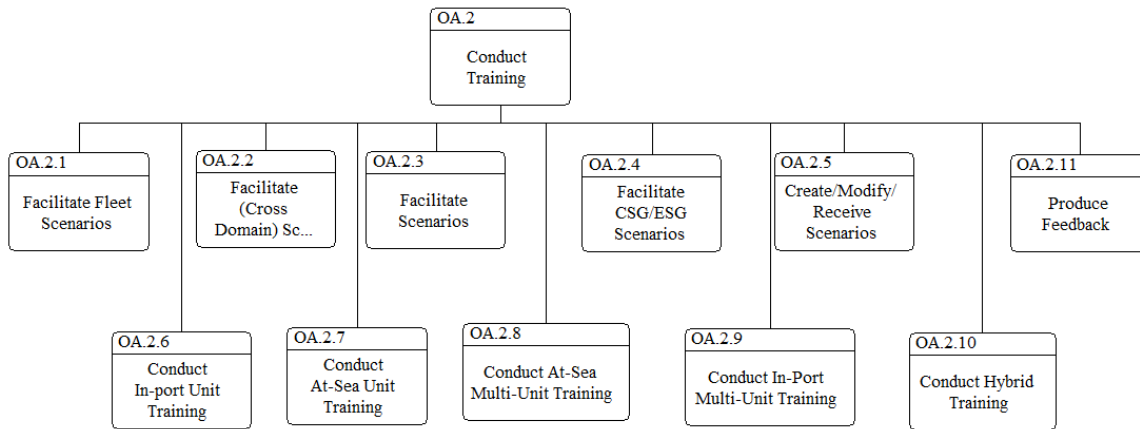


Figure 27. Conduct Training Operational Activity Hierarchy

a. *Facilitate/Create/Modify/Receive Scenarios*

After scenarios have been designed and implemented, the responsibility to facilitate and dictate actions within a scenario will exist. This occurs at much the same command levels as seen in the creation activities. Scenarios will be manipulated, transmitted, and received to match the conditions within which the cognizant commands' respective units can be expected to act. This activity occurs at the fleet, CSG/ESG, unit, multi-unit, and cross-domain levels.

b. *In-port/At-sea/Hybrid Training*

At the heart of cross-domain training exists the capability to link all individual units and simulators, independent of geographic location or seaworthiness, and conduct training events.

c. *Produce Feedback*

The training events will be recorded and analyzed by commands to optimize the scenarios and drive necessary changes in TTPs.

3. Evaluate Training

In order to evaluate the effectiveness of the WFTS, additional operational activities will be accomplished as shown in Figure 28.

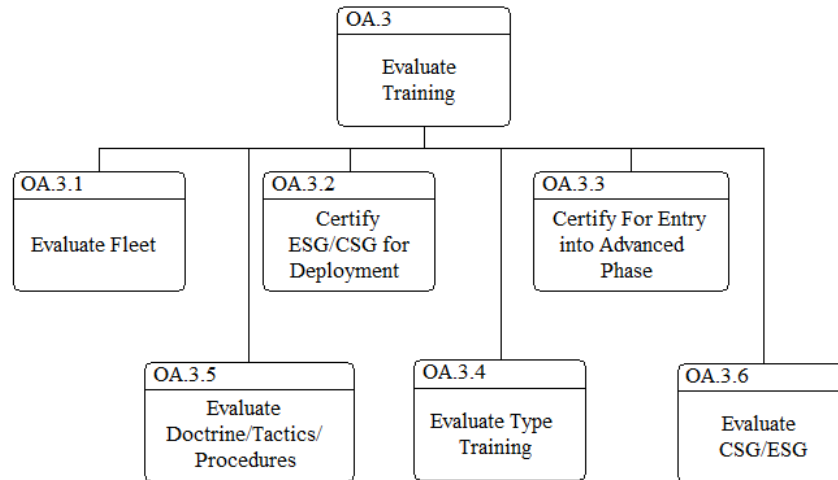


Figure 28. Evaluate Training Operational Activity Hierarchy

a. Evaluate and Certify Fleet/Strike Groups/Units

Prior to and when established in the deployment and advanced phase of the OFRP, commands must be able to meet their numbered-fleet commander's intent. The WFTS will establish the opportunity for shore-based leaders and fleet commanders to evaluate feedback data from training scenarios.

b. Evaluate Doctrine/Tactics/Procedures

As the database of feedback grows, intelligence and tactical development organizations will evaluate warfighter actions within training scenarios to determine whether a more effective action would produce more favorable offensive or defensive outcomes for a given set of conditions.

c. Evaluate Type Training

Operational and tactical leaders will have the ability to evaluate the overall effectiveness of the training provided to various types of vessels.

IX. ANALYSIS OF ALTERNATIVES

This chapter corresponds to the final major phase of the project. These are the steps where a specific solution begins to emerge. Analysis of alternatives is a process in which multiple design options, or solutions, are developed and compared against one another to determine the best solution. The team started this process using a creativity tool called a morphological box to help develop alternative solutions. Next, the team developed the criteria against which the design alternatives would be compared to determine the best solutions.

These design criteria came from the Critical Operating Issues (COI), and the Measures of Effectiveness (MOE) used to measure how well a design meets the requirements. Once the alternatives and grading criteria were developed, the next step was to evaluate how well each alternative meets the specified criteria and assign values for comparison. For this project, the team determined that not all of the criteria should be equally weighted. Swing weights were used to determine which MOEs should be considered of higher importance than others. The assigned values were multiplied by their associated swing weights to determine an overall measure of effectiveness (OMOE) for each design alternative.

A. MORPHOLOGICAL BOX

The design of any system requires choosing the right components to provide the required functionality. The use of a morphological box overcomes the limitations of normal quantitative methods of analysis. Normal quantitative methods, including modeling and simulation, fail to capture the non-quantifiable attributes of the factors involved (Richey 2017). The morphological box approach captures the complexity of a design without the need for a rigorous mathematical approach.

The morphological box approach helps us choose design alternatives that meet our high-level functions. Underneath each high-level function is a list of component alternatives that are composed of similar components designed to meet the higher level function. Design alternatives are built by selecting a number of component alternatives

from each high-level function category. All of the selected components comprise the design alternative. Each design alternative must have, at a minimum, one component to satisfy each of the higher level functions.

Our design alternatives represent the basic level componentry required to build the system. Each of the design alternatives was chosen using a training vignette described further in this chapter. The alternative component list was chosen for each function based on our best estimate of 2030 technology levels and feasibility based on recent military technology history.

To provide simulations, we chose three alternatives.

- **Artificial Intelligence** would provide the simulation a reactive response to user inputs based on concepts derived from machine learning. The AI would study the current battlefield simulation and make intelligent enemy decisions in order to provide the best simulated response. Ideally, this machine learning would be programmed to react according to tactics typically employed by a specified enemy.
- **Manual** control of the simulation would place SMEs in control of the opposition forces. Enemy decisions made in the simulation would need manual input from the SMEs for the simulation to carry out.
- **Pre-Programmed** is a form of simulation in which a SME would write the simulation events and timing of those events from an enemy perspective. The SMEs would provide this simulation script for units to have available and utilize at a later time. Enemy actions would be fixed and predictable after multiple simulation runs.

Communication between the different training nodes was determined by looking at four different communication methods.

- **Hardwire** communications would include fiber optics, DSL, and T-carriers. These components would physically link shore-based facilities with either additional facilities or pier-side ships. The components are not prone to interference and have a relatively low cost. Hardwire has the greatest bandwidth but is limited to stationary connections.
- **Over the Horizon (OTH)** communications would include high frequency radio communications. The ability to greatly extend the network out to sea is extremely beneficial. Using the properties of the atmosphere, the signal can bounce between the surface and the ionosphere to well beyond the range of traditional line-of-sight communications. The bandwidth is

somewhat limited and the hazard of transmitting near personnel is significant.

- **Line-of-Sight (LOS)** communications could include ultra-high frequency (UHF), very-high frequency (VHF), satellite communications, Link 16, Link 11, and Link 4. The properties of these communications allow for higher bandwidths at reduced ranges. Ranges can be extended with repeaters placed either along the surface or at higher altitudes. The limitation is that both the transmitting/receiving antennas must physically see each other. The waveform does not allow for atmospheric bouncing and is more susceptible to degradation from weather phenomena.
- **Satellite Communications** technically use LOS frequencies, but for purposes of this project have been distinguished from other non-satellite LOS communication methods. Satellite LOS communications allow for much greater separation of units as curvature of the Earth is much less of a factor than it is for LOS communications that do not utilize satellite relays.

Providing the simulation to the user could be accomplished using three different methods.

- **Non-Console** hardware could include laptops, handheld computers, or other electronics. The hardware is not designed to represent the consoles or equipment found in the CSG, but represent one or more features that would be found within a CSG. For example, a laptop could run a program designed to simulate the radar console found on a destroyer. The single user interface would provide additional time to learn simple tasks to operate the webfires hardware.
- **Simulated Console** hardware could include aviation simulators, ship combat system simulators, and submarine combat system simulators. The hardware would best represent the actual hardware used in the CSG/ESG with inputs modeled by computer simulations.
- **Actual Console** hardware includes what the user would actually use in the CSG/ESG environment. Actual equipment provides the greatest level of training fidelity and provides the user the greatest learning environment.

Controlling and evaluating the simulation could be accomplished using three methods.

- **Central Control** concept involves a training headquarters that provides both the training scenario and tools to evaluate the simulation in real time. For example, Navy Training Groups are shore-based facilities that broadcast a computer simulation to actual units located in exercise areas. These simulations provide the data for actual units to run exercises

without the need for actual red forces. The simulation is monitored for performance at the shore-based facility.

- **Local Control** concept involves a smaller SME team than a central control facility would have available to it. The vision is that a local control center could be located on the flagship within the CSG/ESG for exercises out to sea, or could be a shore facility located in the fleet concentration areas to handle controlling and evaluating the training event. The SME team at the local control center will provide all control, including event sequence and reaction to user decisions. This is intended to be similar to central control, but on a smaller scale, while adding the capability to establish a local control center for strike groups that are far out to sea.
- **Unit Control** concept involves non-SME members running training events at the unit level. For example, if two helicopters wished to conduct unit-level training at sea they could control their own training event. For a surface ship, this control method would be very similar to using the Battle Force Tactical Trainer (BFTT) to perform training exercises. For this project, unit control does not mean that one of those units must be in control of the simulation, but rather it means that units have the capability to control the simulation if so desired. Units capable of controlling simulations at the unit level could still take part in training exercises where control over the simulation rests with a central station.

How the data is shared between the nodes of the network can be modeled using three network topologies.

- **Single Star Networks** rely on a single node to transmit and receive data between the other training nodes. An example of this network topology would be training group centers. The data is sent out and received by one node and rebroadcasted to the CSG/ESG.
- **Multiple Star Networks** are similar to single star networks but include links that group single star networks into multiple star networks. The additional capability provides at-sea and shore units to operate on the same network.
- **Mesh Networks** would allow any unit to directly communicate with any other unit in the network. With the mesh network, each unit has its own capability to communicate with other units in the WFTS.

Storing the training and feedback data is possible using three methods.

- **Centralized** data storage would occur at off-site data storage locations. Similar to cloud storage, the data is accessible anywhere on the network and managed by third-party support.

- **Unit** data storage could include a server located on each unit within the CSG/ESG that captures the data from the exercises in which that unit participates. This data could then be uploaded to a centralized network without the need for physical transportation of portable media devices.
- **Portable Media** could include CDs, external HDDs, or USB memory. This would be applicable to unit-level training where network connectivity may not be feasible.

The alternative methods to accomplish the major architecture functions were placed into the morphological box as shown in Table 9.

Table 9. Morphological Box

| Functions | | | | | |
|---------------------------|--------------------|--------------------------------|---------------------------|-------------------------------|----------------------------|
| Provide Simulation | Communicate | Stimulate Sensors/Units | Control Simulation | Interface With Network | Store Feedback Data |
| ARTIFICIAL INTEL | HARDWIRE | NON-CONSOLE | CENTRAL CONTROL | SINGLE STAR | CENTRALIZED |
| MANUAL | OTH | SIMULATED CONSOLE | LOCAL CONTROL | MULTIPLE STAR | UNIT |
| PRE-PROGRAMMED | LOS | ACTUAL CONSOLE | UNIT CONTROL | MESH | PORTABLE MEDIA |
| | SAT COMMS | | | | |

The team has chosen all of the design alternatives for evaluation from this morphological box. Design alternatives are chosen by selecting one or more of the options under each of the six major system functions.

B. DESIGN ALTERNATIVES

From the morphological box, the team chose several design alternatives intended to showcase various aspects of the WFTS. Ultimately, the team chose to study a total of nine different design alternatives. Each of these design alternatives has been numbered in order of assessed training value, where option one had the highest overall training value and option nine had the lowest overall training value.

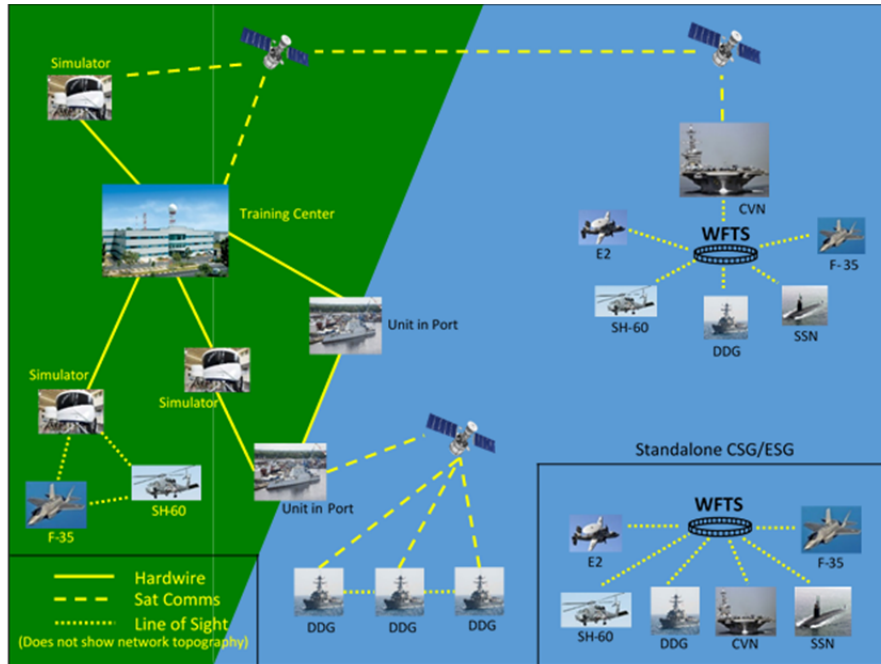
1. Fully capable system addresses all major capability gaps identified.
2. Strike group out to sea integrated with a shore-based simulator network.

3. A ship out to sea integrated with a ship in port.
4. A squadron of similar units integrating for training out to sea.
5. Ships in port integrating with a shore based simulator.
6. A strike group conducting sustainment training at sea.
7. Fleet synthetic training exercise integrating in port or at sea units during the integrated phase.
8. Low-fidelity trainer integrating units at sea and in port.
9. Single unit in port being fed a scenario from a local training center.

Each of these options is discussed in greater detail in the following sections.

1. Design Alternative One

Design Alternative One (DA1) was designed to be the most capable WFTS, integrating both in-port and at-sea operational units with simulators to perform training in all three phases of the OFRP. This option was designed to be capable of performing the training scenarios of all of the other design alternatives combined. A decision maker would choose this option when an unlimited budget is available. Figure 29 represents the networking and interfacing capabilities expected from DA1.



Images from businessinsider.com, wikipedia.org, huntingtoningalls.com, nationstates.net, suwalls.com, sandiegouniontribune.com, ndtv.com, and boeing.com.

Figure 29. Design Alternative One Network Interface Diagram

The morphological box for DA1 is shown in Table 10. The cells highlighted in red and bolded are the options selected for DA1.

Table 10. Design Alternative One Functions

| Functions | | | | | |
|-------------------------|------------------|--------------------------|---------------------|------------------------|---------------------|
| Provide Simulation | Communicate | Stimulate Sensors/Units | Control Simulation | Interface With Network | Store Feedback Data |
| ARTIFICIAL INTEL | HARDWIRE | NON-CONSOLE | CENTRAL CONTROL | SINGLE STAR | CENTRALIZED |
| MANUAL | OTH | SIMULATED CONSOLE | LOCAL CONTROL | MULTIPLE STAR | UNIT |
| PRE-PROGRAMMED | LOS | ACTUAL CONSOLE | UNIT CONTROL | MESH | PORTABLE MEDIA |
| | SAT COMMS | | | | |

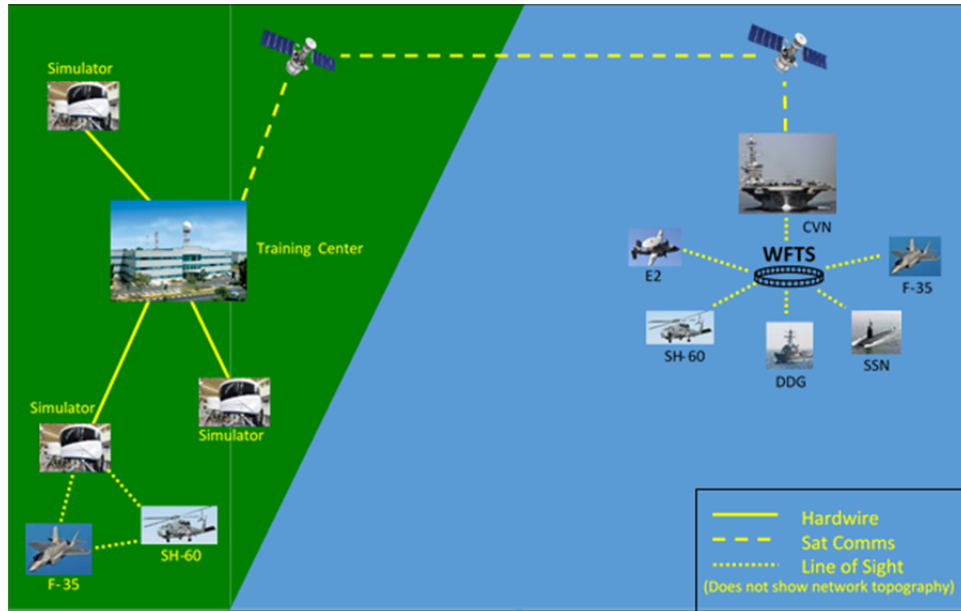
The AI option provides high fidelity simulations that can be repeated frequently during the basic and sustainment phases. The manual simulations, great for the integrated

training phase, allow for the highest fidelity training exercises at the hands of SMEs, but with fewer repetitions due to the resources involved in such simulations. The combination of using both AI and manually controlled simulations can provide very high fidelity simulations that can be conducted with optimal repetition. By including the option for all four communications methods, we can use each method where appropriate to allow for full integration of both in-port and at-sea units with shore-based simulators.

Units would be conducting webfires training using actual combat systems, while simulated combat systems (high fidelity simulators) would be used to conduct webfires training at shore-based facilities. When each unit has the capability to control the simulation, the units do not have to rely upon the availability of a central or local control station to conduct training exercises. Combined with the mesh network architecture, where any unit or simulator can establish a connection with any other unit or simulator, any two units available for training can link up and conduct training simulations together. For DA1, the option was chosen to store feedback data on a centralized server. This allows faster and greater access to training data across the fleet as each unit can review or study exercises from other units. Units can also download or stream simulations from the standardized, central database.

2. Design Alternative Two

DA2 was chosen to meet the requirements for conducting strike group training exercises out to sea by integrating with simulators in port. An example of when this alternative might be desirable is during the beginning of the integrated phase, when the strike group ships go out to sea, but the units of the air wing will participate in the exercise from a shore training facility. When the strike group is fully integrated, such as during the later stages of the integration phase or even the sustainment phase, the simulator facilities on shore might consist purely of opposition forces. Figure 30 represents the networking and interfacing capabilities expected from DA2.



Images from businessinsider.com, wikipedia.org, huntingtoningalls.com, nationstates.net, suwalls.com, ndtv.com, and boeing.com.

Figure 30. Design Alternative Two Network Interface Diagram

The morphological box for DA2 is shown in Table 11. The cells highlighted in red and bolded are the options selected for DA2.

Table 11. Design Alternative Two Functions

| Functions | | | | | |
|-----------------------|------------------|--------------------------|------------------------|------------------------|---------------------|
| Provide Simulation | Communicate | Stimulate Sensors/Units | Control Simulation | Interface With Network | Store Feedback Data |
| ARTIFICIAL INTEL | HARDWIRE | NON-CONSOLE | CENTRAL CONTROL | SINGLE STAR | CENTRALIZED |
| MANUAL | OTH | SIMULATED CONSOLE | LOCAL CONTROL | MULTIPLE STAR | UNIT |
| PRE-PROGRAMMED | LOS | ACTUAL CONSOLE | UNIT CONTROL | MESH | PORTABLE MEDIA |
| | SAT COMMS | | | | |

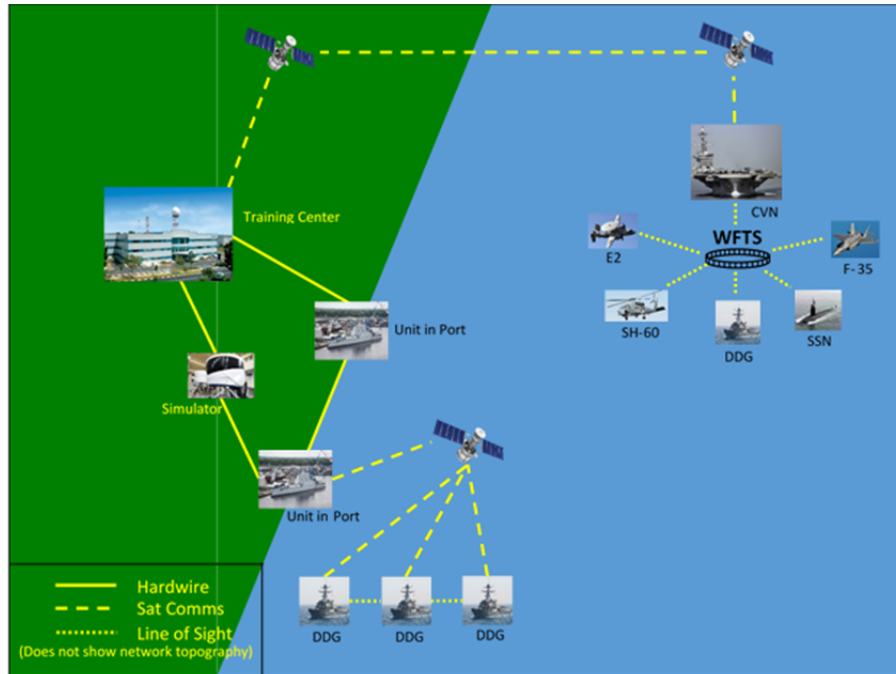
As in DA1, the combination of manual and pre-programmed simulations allows for high fidelity and high repetition. By using preprogrammed enemy actions during simulations instead of enemy actions simulated with AI, we anticipate a reduced

effectiveness. However, with the option to communicate via hardwire, LOS, and satellite communications, the major communication methods for transferring high data volumes either in port or at sea are maintained. This system maintains full integration capability between units and simulators.

The use of actual and simulated combat systems maintains a high degree of fidelity. DA2 utilizes a central control of the simulation, relying on a shore-based central control facility to push the simulation to the strike group via satellite data networks. The multiple star network option allows for multiple shore-based simulators to form the first star network with the central control station, which can then transfer the simulation data to the strike group flagship. The flagship would then act as the hub for a second star network made up of the strike group units at sea. Data could be recorded and stored at a centralized facility on shore.

3. Design Alternative Three

DA3 focuses on the elements needed to integrate units at sea to conduct simulated training exercises with units in port. This design alternative came about because it is not always possible to get all of the desired participants either at sea together or in port together on a regular basis. Sometimes equipment casualties and the need for other training events often dictate in port and at sea schedules. That concern goes away with this alternative as it allows for integration between at-sea and in-port units. Figure 31 represents the networking and interfacing capabilities expected from DA3.



Images from businessinsider.com, wikipedia.org, huntingtoningalls.com, nationstates.net, suwalls.com, sandiegouniontribune.com, ndtv.com, and boeing.com.

Figure 31. Design Alternative Three Network Interface Diagram

The morphological box for DA3 is shown in Table 12. The cells highlighted in red and bolded are the options selected for DA3.

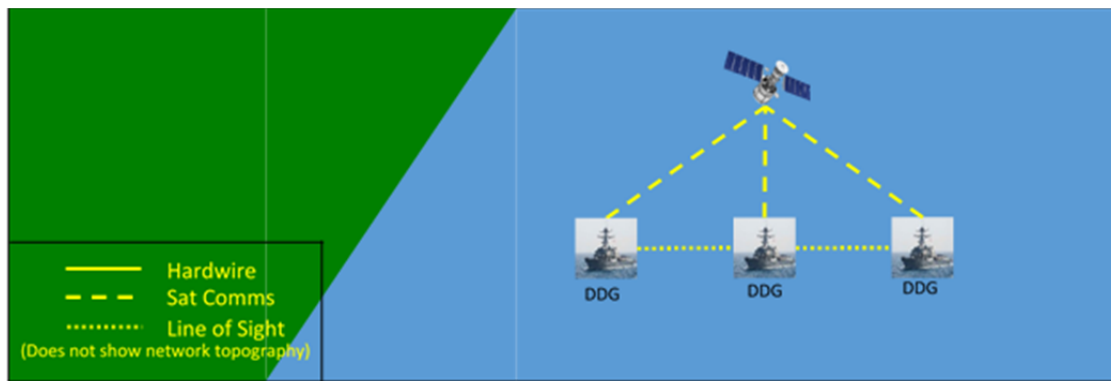
Table 12. Design Alternative Three Functions

| Functions | | | | | |
|-----------------------|------------------|--------------------------|------------------------|------------------------|---------------------|
| Provide Simulation | Communicate | Stimulate Sensors/Units | Control Simulation | Interface With Network | Store Feedback Data |
| ARTIFICIAL INTEL | HARDWIRE | NON-CONSOLE | CENTRAL CONTROL | SINGLE STAR | CENTRALIZED |
| MANUAL | OTH | SIMULATED CONSOLE | LOCAL CONTROL | MULTIPLE STAR | UNIT |
| PRE-PROGRAMMED | LOS | ACTUAL CONSOLE | UNIT CONTROL | MESH | PORTABLE MEDIA |
| | SAT COMMS | | | | |

The combination of manual and preprogrammed simulations allows for high fidelity and frequent repetition. A shore-based central control station would provide the hub of a star network. Hardwire communications can be used to link units in port to the hub, while units at sea would be connected to the hub via satellite communication links. In the event an in-port unit's combat system is down, that unit can relocate its watch teams to a nearby simulator facility located at its fleet concentration area.

4. Design Alternative Four

DA4 is designed to allow at sea training of a squadron of units such as a Surface Action Group or an air wing, but not a complete strike group. The intention of this design alternative is to implement webfires training into type group (TYCOM) training exercises that take place before integrating with the rest of the strike group. Figure 32 represents the networking and interfacing capabilities expected from DA4. It is not necessarily limited to the destroyer squadron SAG portrayed in the figure. The type group could be made up of a submarine squadron, an air wing, or any other webfires-capable squadron.



Images from huntingtoningalls.com.

Figure 32. Design Alternative Four Network Interface Diagram

The morphological box for DA4 is shown in Table 13. The cells highlighted in red and bolded are the options selected for DA4.

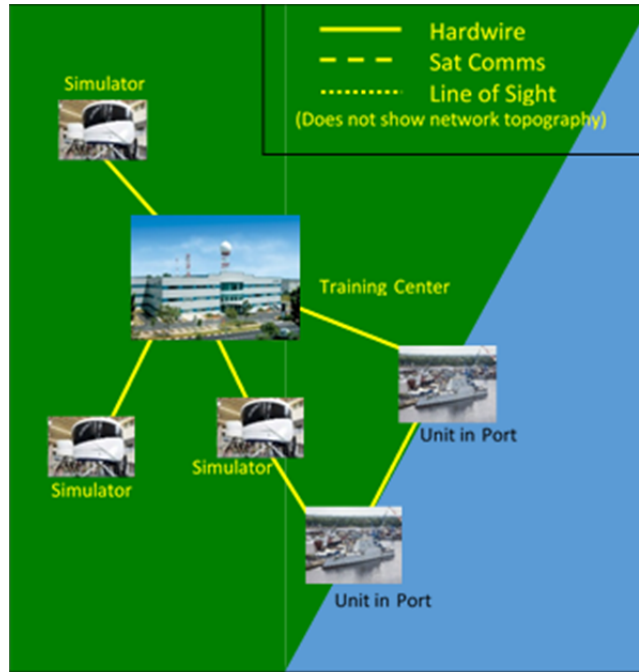
Table 13. Design Alternative Four Functions

| Functions | | | | | |
|-----------------------|------------------|-------------------------|---------------------|------------------------|---------------------|
| Provide Simulation | Communicate | Stimulate Sensors/Units | Control Simulation | Interface With Network | Store Feedback Data |
| ARTIFICIAL INTEL | HARDWIRE | NON-CONSOLE | CENTRAL CONTROL | SINGLE STAR | CENTRALIZED |
| MANUAL | OTH | SIMULATED CONSOLE | LOCAL CONTROL | MULTIPLE STAR | UNIT |
| PRE-PROGRAMMED | LOS | ACTUAL CONSOLE | UNIT CONTROL | MESH | PORTABLE MEDIA |
| | SAT COMMS | | | | |

The combination of manual and preprogrammed simulations allows for high fidelity and optimal repetition. The difference for this alternative is that the manual control would most likely be carried out by one of the units designated as the unit controlling the simulation. LOS and satellite communications provides ample data rates between units integrated at sea. Any decrease in fidelity from not having the SMEs associated with a central control station controlling opposition forces will be offset by the increase in fidelity from the simulations taking place on the actual webfires combat systems via combat system simulators. Without a connection to a central or local hub to control the simulation, units participating in this type of at-sea training must have the capability for unit control. Units would be directly integrated with each other using a mesh network, with a unit designated as the control unit for that simulation.

5. Design Alternative Five

DA5 allows multiple ships in port to integrate with a shore-based simulator facility. This is similar to the current FST system, but with the notable addition of also running preprogrammed scenarios. This design alternative could be used for an entire strike group in port participating with a shore-based simulation facility, or this design alternative could be used for only one ship in port participating with a shore-based simulation facility. Figure 33 represents the networking and interfacing capabilities expected from DA5.



Images from sandiegouniontribune.com, ndtv.com, and boeing.com.

Figure 33. Design Alternative Five Network Interface Diagram

The morphological box for DA5 is shown in Table 14. The cells highlighted in red and bolded are the options selected for DA5.

Table 14. Design Alternative Five Functions

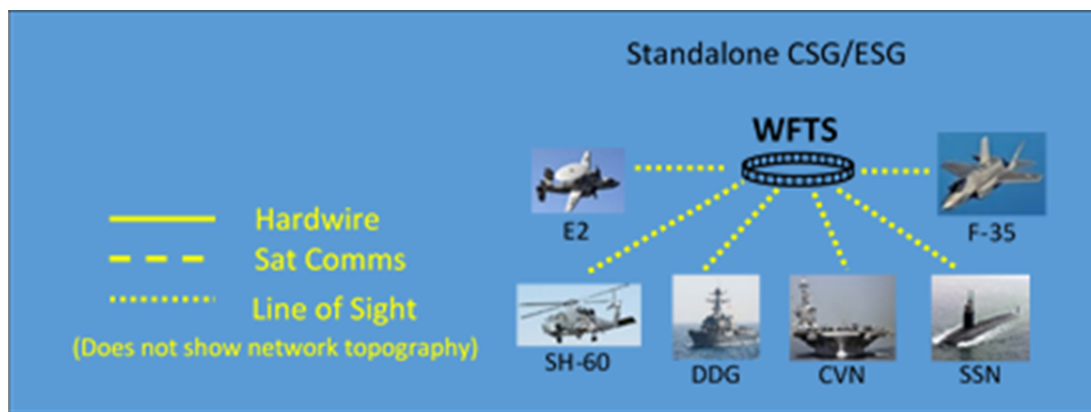
| Functions | | | | | |
|-----------------------|-----------------|--------------------------|------------------------|------------------------|---------------------|
| Provide Simulation | Communicate | Stimulate Sensors/Units | Control Simulation | Interface With Network | Store Feedback Data |
| ARTIFICIAL INTEL | HARDWIRE | NON-CONSOLE | CENTRAL CONTROL | SINGLE STAR | CENTRALIZED |
| MANUAL | OTH | SIMULATED CONSOLE | LOCAL CONTROL | MULTIPLE STAR | UNIT |
| PRE-PROGRAMMED | LOS | ACTUAL CONSOLE | UNIT CONTROL | MESH | PORTABLE MEDIA |
| | SAT COMMS | | | | |

The combination of manual and preprogrammed simulations allows for high fidelity and optimal repetition. Since all units are stationary, either on land or in port,

hardwire will provide a cost-effective solution for communications at high data rates. Simulated combat system consoles and actual combat systems consoles were selected to represent the actual combat systems on the ship as well as the simulator facility on shore. The redundant communications paths of a mesh network are not necessary for this hardwired training network, so a single star network should suffice. Units can store their own data for later evaluation.

6. Design Alternative Six

The vision for DA6 was a strike group conducting sustainment training at sea, far from shore-based simulator facilities. The idea here is the strike group might be making a long ocean transit as part of a deployment or might just be out to sea together for sustainment training as a strike group after returning from a deployment. One goal for this design alternative was minimal reliance upon shore facilities while conducting training. Training associated with DA6 is expected to be the closest design alternative to actual webfires employment. Figure 34 represents the networking and interfacing capabilities expected from DA6.



Images from businessinsider.com, wikipedia.org, huntingtoningalls.com, nationstates.net, and suwalls.com.

Figure 34. Design Alternative Six Network Interface Diagram

The morphological box for DA6 is shown in Table 15. The cells highlighted in red and bolded are the options selected for DA6.

Table 15. Design Alternative Six Functions

| Functions | | | | | |
|-----------------------|-------------|-------------------------|----------------------|------------------------|---------------------|
| Provide Simulation | Communicate | Stimulate Sensors/Units | Control Simulation | Interface With Network | Store Feedback Data |
| ARTIFICIAL INTEL | HARDWIRE | NON-CONSOLE | CENTRAL CONTROL | SINGLE STAR | CENTRALIZED |
| MANUAL | OTH | SIMULATED CONSOLE | LOCAL CONTROL | MULTIPLE STAR | UNIT |
| PRE-PROGRAMMED | LOS | ACTUAL CONSOLE | UNIT CONTROL | MESH | PORTABLE MEDIA |
| | SAT COMMS | | | | |

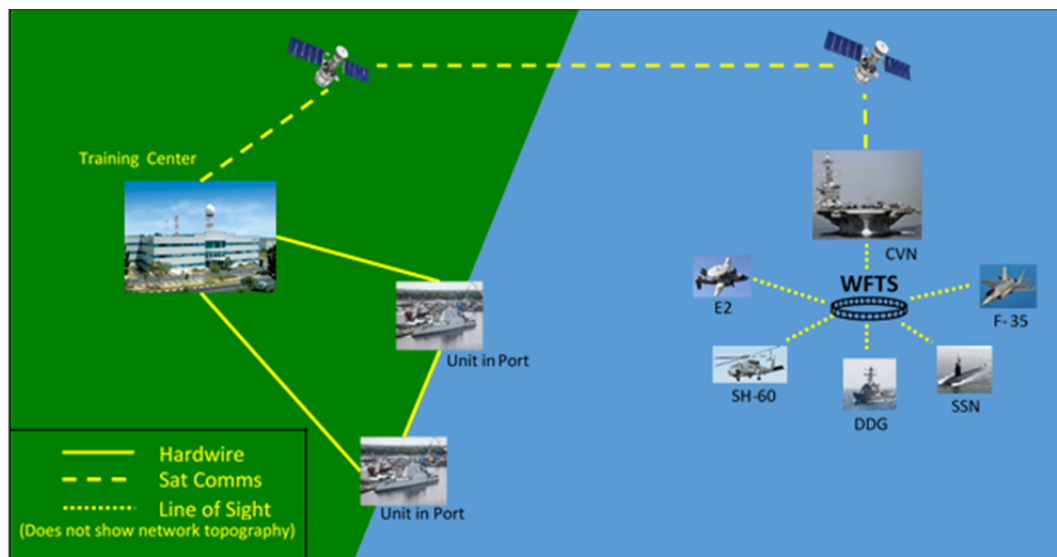
The combination of manual and preprogrammed simulations allows for high fidelity and frequent repetition. Here the SMEs controlling the exercise would be located on the flagship of the strike group. These could be a few civilian contractors whose expertise is in the enemy's tactics, or they might be members of the U.S. Navy's intelligence community, or Weapons and Tactics Instructors who might have expertise comparable to the SMEs found at shore training facilities, such as the tactical training groups, but are still recognized as experts in their warfare areas. Because this training scenario is isolated to the strike group out to sea, LOS was chosen exclusively.

Satellite communications might not be available in the environment where the strike group is expected to be employing webfires, and so this WFTS design does not use satellites to communicate. Actual combat consoles were chosen because each unit in the strike group will be conducting the training simulation using their actual combat units. The difference would be that the consoles would be in a training mode that allows them to display simulated sensor data. Simulation would come from a local control center residing within the strike group, likely the CVN or the LHD/LHA. Units would interface using a WFTS mesh network, which is the network architecture that the webfires system

would be expected to employ. Each unit in the strike group would store its own performance data locally.

7. Design Alternative Seven

DA7 aims to represent a blend of the current FST architecture and the Composite Training Unit Exercise (COMPTUEX) architecture. The major difference between this design alternative and FST or COMPTUEX, is that this design allows for the in-port units to participate alongside at-sea units. Figure 35 represents the networking and interfacing capabilities expected from DA7.



Images from businessinsider.com, wikipedia.org, huntingtoningalls.com, nationstates.net, suwalls.com, sandiegouniontribune.com, and boeing.com.

Figure 35. Design Alternative Seven Network Interface Diagram

The morphological box for DA7 is shown in Table 16. The cells highlighted in red and bolded are the options selected for DA7.

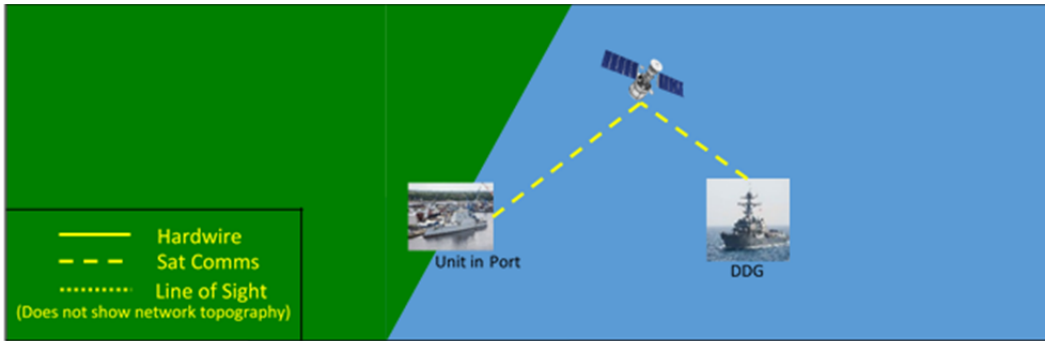
Table 16. Design Alternative Seven Functions

| Functions | | | | | |
|--------------------|------------------|--------------------------|------------------------|------------------------|---------------------|
| Provide Simulation | Communicate | Stimulate Sensors/Units | Control Simulation | Interface With Network | Store Feedback Data |
| ARTIFICIAL INTEL | HARDWIRE | NON-CONSOLE | CENTRAL CONTROL | SINGLE STAR | CENTRALIZED |
| MANUAL | OTH | SIMULATED CONSOLE | LOCAL CONTROL | MULTIPLE STAR | UNIT |
| PRE-PROGRAMMED | LOS | ACTUAL CONSOLE | UNIT CONTROL | MESH | PORTABLE MEDIA |
| | SAT COMMS | | | | |

For this design alternative all simulations are provided with manual control of the opposition forces by trained SMEs located at one of the tactical training groups. Units at sea would communicate simulation data using LOS communications, while units in port would use hardwire communications. To network the in-port units with the units at sea, satellite communications would be used. This communication would occur using a single star network with a central control station hub to push the simulations out to the participants' actual combat systems or simulator combat system consoles located at shore-based facilities. The central control station would store the data for performance evaluation.

8. Design Alternative Eight

DA8 represents units in port and at sea participating in a low fidelity trainer scenario. This type of training might be valuable at the end of the basic phase in preparation for entering the integrated phase, or it might be useful in the sustainment phase to maintain proficiency. Figure 36 represents the networking and interfacing capabilities expected from DA8.



Images from huntingtoningalls.com and sandiegouniontribune.com.

Figure 36. Design Alternative Eight Network Interface Diagram

The morphological box for DA8 is shown in Table 17. The cells highlighted in red and bolded are the options selected for DA8.

Table 17. Design Alternative Eight Functions

| Functions | | | | | |
|-----------------------|------------------|-------------------------|---------------------|------------------------|-----------------------|
| Provide Simulation | Communicate | Stimulate Sensors/Units | Control Simulation | Interface With Network | Store Feedback Data |
| ARTIFICIAL INTEL | HARDWIRE | NON-CONSOLE | CENTRAL CONTROL | SINGLE STAR | CENTRALIZED |
| MANUAL | OTH | SIMULATED CONSOLE | LOCAL CONTROL | MULTIPLE STAR | UNIT |
| PRE-PROGRAMMED | LOS | ACTUAL CONSOLE | UNIT CONTROL | MESH | PORTABLE MEDIA |
| | SAT COMMS | | | | |

This alternative uses simple preprogrammed simulations designed to maintain proficiency in entry level tactics and decisions. Preprogrammed simulations were chosen for their ease of uploading and repetition. A non-console system was chosen to represent a low fidelity trainer such as a laptop, where a warfighter can log in when time is available and interface with another participant. Hardwire communications would be used for units on land, while satellite communications would be used to interface with units at sea. At each end, units would likely network into local hubs that would then

communicate with each other, but control of the simulations would reside with one of the participating units.

9. Design Alternative Nine

DA9 represents a single unit in port receiving a preprogrammed scenario from a local shore-based simulation facility. This type of scenario can be used during any of the phases, depending on the preprogrammed simulation provided. During the integrated phase, integration can be simulated by preprogramming virtual participants into the simulation. Figure 37 represents the networking and interfacing capabilities expected from DA9.



Images from sandiegouniontribune.com and boeing.com.

Figure 37. Design Alternative Nine Network Interface Diagram

The morphological box for DA9 is shown in Table 18. The cells highlighted in red and bolded are the options selected for DA9.

Table 18. Design Alternative Nine Functions

| Functions | | | | | |
|-----------------------|-----------------|-------------------------|----------------------|------------------------|---------------------|
| Provide Simulation | Communicate | Stimulate Sensors/Units | Control Simulation | Interface With Network | Store Feedback Data |
| ARTIFICIAL INTEL | HARDWIRE | NON-CONSOLE | CENTRAL CONTROL | SINGLE STAR | CENTRALIZED |
| MANUAL | OTH | SIMULATED CONSOLE | LOCAL CONTROL | MULTIPLE STAR | UNIT |
| PRE-PROGRAMMED | LOS | ACTUAL CONSOLE | UNIT CONTROL | MESH | PORTABLE MEDIA |
| | SAT COMMS | | | | |

Preprogrammed simulation allows for frequent repetition as the scenario can be run multiple times according to the unit's own schedule. As the unit is in port, hardware provides a cost-effective means of communication back to a simulator facility. The unit performs the exercises using its own actual combat systems to maintain fidelity. A local control facility would transmit the simulation to the unit via a star network. This allows multiple units to utilize the same local control center to simultaneously conduct different training scenarios. Units would store their own performance data to have on hand for evaluation upon completion of the training.

C. TRADE-OFF BETWEEN COMPONENTS

The team identified six high-level system functions of the WFTS. These six high-level system functions are: provide simulation, communicate, stimulate units, control simulation, interface with network, and store data. Based on these system functions, the team identified three to four methods to fulfill each function. After identifying the list of methods, the team conducted a trade-off analysis of the components to determine the advantages and disadvantages of each method.

1. Providing Simulation

Artificial intelligence has the potential to mimic enemy's tactics while not relying on the SMEs to manually run the scenarios. When the AI is programmed with input from the SME, the major benefit is that units can now run higher fidelity preprogrammed scenarios that do not rely on the availability or logistical burdens that must be considered when running high fidelity scenarios through a central training facility, as is the case during COMPTUEX. AI scenarios provide frequent repetition training opportunities while maintaining the high fidelity enemy actions seen with SME controlled systems. The problem with AI systems is the high cost and time commitment necessary for the AI programming.

Manually controlled simulations rely heavily on the knowledge of SMEs to ensure the fidelity of enemy tactics employed and their responses to friendly actions. At the hands of SMEs, manually controlled simulation provides the highest fidelity enemy tactics that warfighters can train against. The trade-off for the high fidelity achieved in

manual simulations, though, is the limited number of repetitions in conducting exercises. The resource requirements to ensure SMEs are available for every training exercise of every unit would be prohibitive.

Preprogrammed simulations are low cost and easily repeatable so that warfighters can make evaluations and adjustments to improve performance with each iteration. However, the trade off with preprogrammed simulations is that they typically have low tactical fidelity and events become predictable after several iterations.

2. Communicate

Hardwire communications such as fiber optics or Local Area Network (LAN) lines provide the highest data rates and are inexpensive to implement over short distances. However, the drawback to the great data rates hardwire can provide is limited by mobility. Hardwire communications do not lend themselves to effective use between ships at sea.

Over-the-Horizon communications provide at-sea communication capabilities using High Frequency (HF) waves that can bounce off the atmosphere to travel great distances. However, data rates associated with HF communications are expected to be too low to transmit the amount of data needed for webfires training scenarios. Additionally, HF communications can pose a radiation hazard for personnel near the antennas, such as may be the case with multiple ships in port.

Line-of-sight communications offer high data rates for units that are in direct sight of one another. The downside of LOS communications is that the curvature of the Earth limits the ranges in which LOS communications can be used without the need for relays or very high antennas.

Satellite communications are technically LOS communications using satellites as relays. These communications offer similar data rates to other LOS communications, but allow for communicating that data over much greater ranges. The trade-off is that the need for satellites makes this option very expensive and these satellites are not always available for training due to competing priorities.

3. Stimulate Units

Actual combat systems provide the highest fidelity but are the most expensive to build and maintain. Actual combat systems typically come with higher manpower demands as each relevant console needs an operator to perform that console's functions. Additionally, performing training on actual combat systems might not be possible if those systems are down for maintenance.

Simulated combat systems provide medium fidelity and, depending on the location, can be utilized by multiple units. Simulated combat systems can be used as a backup when actual combat systems are unavailable, but typically they do not offer the same fidelity.

Non-combat system consoles such as a laptop or a stand-alone system are the cheapest and offer the greatest potential for repetition. Simulations on non-combat systems are assessed to have the lowest fidelity of training.

4. Control Simulation

Both central control and local control are great for unity of command, but each can become a single point of failure because of its lack of redundancy. By contrast, unit control does not rely on a central or local control node; every Webfires capable unit can control the simulation.

5. Interface with Network

Both the star network and multiple star networks are the most common topology. A central hub controls and monitors all connected units. It is relatively easy for the units to connect and disconnect from the network. The disadvantage of this type of network is its reliance on the central hub. When the central hub fails, it brings down the entire network. By contrast, a mesh network is much more robust and reliable. When one of the nodes goes down, it does not bring down the entire network.

6. Store Data

Centralized storage contains all available data and allows easy access for all units. However, due to its lack of redundancy it can become a single point of failure. Local storage provides the unit with easy access to its own data without relying on the network. While a portable medium is very convenient and low cost, it takes a long time to transfer data to its destination. The other disadvantage of both local storage and portable media is that they only contain partial picture data.

The results of the components trade-off analysis are summarized in Appendix C.

D. COST EFFECTIVE TRADE-OFF

As stated in Chapter II, cost effectiveness is addressed from a qualitative rather than quantitative analysis here. The cost-effective trade-offs will now be discussed in greater detail. After an analysis of the previously described components, we find the more capable systems tend to have higher costs associated with them. This is expected; as capabilities increase, expected costs often increase, too. Nevertheless, there are ways to reduce costs throughout the process without loss of capability.

The major capability gaps identified were a lack of repetition and a lack of integration. Increasing repetition by conducting training at sea more often would lead to cost increases. Training simulations, by comparison, can be conducted more cheaply and quickly than getting underway or conducting flight operations. Imagine a unit is going to conduct five training exercises at sea. Using training simulations, the unit might replace two of those at-sea exercises with four to six in-port training exercises in the same time. Costs would be reduced by not burning the fuel or paying for port operations to get underway and return. Additionally, the unit will have now completed seven to nine training exercises, three at sea and four to six simulated, in the same time it had originally planned to conduct only five exercises. Simulation allows greater frequency of training at reduced costs by reducing the underway time needed for training.

By utilizing lower fidelity preprogrammed simulations, the costs of simulation could be even further reduced in comparison with the more expensive simulations such as those using AI or SMEs in manual control. Using non-combat system consoles could

further reduce the cost to provide training simulations, but again, at the expense of fidelity. The major trade-offs seem to be between repetition, fidelity, and costs. A reasonable trade-off seems to be to focus on low cost, low fidelity, and highly repetitive simulations earlier in the OFRP. As training progresses, low cost simulations could give way to more expensive, higher fidelity, less repeatable simulations, and live exercises.

Increasing the training simulation capacity and integration capability will be a large capital expense. Nevertheless, there is potential for great cost efficiency if the same training proficiency can be obtained while decreasing underway time or flight hours. If unit or mission loss can be prevented through more effective warfighting, the cost efficiency is even greater.

E. CRITICAL OPERATING ISSUES AND MEASURES OF EFFECTIVENESS

From the morphological box provided earlier in this chapter, the team chose methods to accomplish each function and to evaluate how well those options meet training objectives. As a first step, the specific evaluation criteria must be developed. The team developed these criteria by reviewing the capability and functional requirements and by developing a list of Critical Operating Issues (COI). Each COI was then broken into several Measures of Effectiveness (MOE).

1. COI 1 – How well does the system support training during the OFRP cycle?
 - MOE 1.1: System fit into the Basic Phase
 - MOE 1.2: System fit into the Integrated Phase
 - MOE 1.3: System fit into the Sustainment Phase
2. COI 2 – How well does the system train to a near-peer threat?
 - MOE 2.1: Scenario management
 - MOE 2.2: Understanding enemy
 - MOE 2.3: Identify warfighter decisions
3. COI 3 – How well does the system provide relevant data to support evaluation?

MOE 3.1: Automation of data processing

4. COI 4 – How well does the system integrate units and simulators?

MOE 4.1: Integration within units or simulators

MOE 4.2: Integration between units and simulators

MOE 4.3: Integration at sea

MOE 4.4: Integration at sea with in-port units

MOE 4.5: Integration in port

5. COI 5 – How well does system implement the principles of high-velocity learning?

MOE 5.1: Fidelity

MOE 5.2: Repetition

MOE 5.3: Retention

Descriptions of each COI and MOE are provided in the following paragraphs.

1. COI 1 – How Well Does the System Support Training during the OFRP Cycle?

For this project, it was important to the team that the webfires training architecture fits into the existing greater navy training architecture, such as the OFRP, where feasible. Training takes place during the OFRP primarily in three phases: the basic, integrated, and sustainment phases. It was desirable that the proposed webfires training system also fit into these three phases for ease of transition and implementation.

a. MOE 1.1: System Fit into the Basic Phase

This MOE is designed to evaluate how well the proposed webfires training architecture meets the unit-level training expectations laid out in the Basic Phase, including both the at-sea and in-port portions.

b. MOE 1.2: System Fit into the Integrated Phase

This MOE is designed to evaluate how well the proposed webfires training architecture meets the training expectations laid out in the Integrated Phase, including

both the at-sea and in-port portions. This MOE is also intended to capture how well the system can perform unit training requirements that are periodically recurring from the basic phase.

c. MOE 1.3: System Fit into the Sustainment Phase

This MOE is designed to evaluate how well the proposed webfires training architecture meets the training expectations laid out in the Sustainment Phase, to including both the at-sea and in-port portions. This MOE is also intended to capture how well the system can perform both unit and multi-unit training requirements that are periodically recurring from the basic and integrated phases.

2. COI 2 – How Well Does the System Support Training to a Near-Peer Threat?

This COI is designed to assess how well the system supports training to a high level, complex threat scenario. The ultimate purpose of the training architecture is to train warfighters in the doctrines and tactics used to counter an enemy threat.

a. MOE 2.1: Scenario Management

This MOE is designed to encompass an array of performance measures that could be used to determine how difficult a scenario is to manage. These factors would include the difficulty in creating and modifying a scenario, the difficulty in scheduling a scenario, and the difficulty in bringing participants together to take part in a designated scenario.

b. MOE 2.2: Understanding Enemy

This MOE is designed to capture how well the warfighter can understand a given enemy's intentions and predict the near-future actions of that enemy. Understanding an enemy's likely course of action is important to countering that enemy. One goal of this training architecture is to ensure the enemy portrayed in simulations is represented as accurately as possible.

c. MOE 2.3: Identify Warfighter Decisions

This MOE is designed to capture the actions and decisions of the warfighter and analyze the impact of those decisions on the simulation. The intent is to identify the decisions made and, through an analysis and feedback process, determine whether the decisions made were the correct decisions in accordance with doctrine and training, tactics, and procedures.

3. COI 3 – How Well Does the System Provide Relevant Data to Support Evaluation and Feedback?

An important aspect of effective training is an iterative process involving training, evaluation, and feedback. After engaging with stakeholders and from the team's own fleet experience, it was determined that delays in the evaluation process cause delays in future training opportunities. Additionally, it was determined that evaluation and feedback are most effective when they are provided in a timely manner upon completion of the training simulation.

a. MOE 3.1: Automation of Data Processing

This MOE is designed to capture the automation in processing that data that may be used to evaluate a unit or warfighter's performance during a scenario. Stakeholder interviews cited a several hour delay in the evaluation and feedback process when simulation tapes need to be reviewed prior to providing performance feedback. If the system could be programmed to automate the evaluation process, it is possible to evaluate at near real time. Additionally, performance feedback data could be provided at near real time. Reducing the delay in receiving feedback could reduce the delay before commencing the next iteration of training.

4. COI 4 – How Well Does the System Integrate Units and Simulators?

Integration is one of the largest gaps the team identified through stakeholder interactions. Air, surface, and subsurface communities all have simulators to train their respective communities, but those simulators rarely have the capability to integrate with other simulators of the same community, let alone the simulators of other communities.

The team determined if integration is the ultimate goal of a strike group employing webfires, then integration between the communities must take place as early and often as is feasible. Integrating simulators and units across all communities should help achieve these integration goals.

a. MOE 4.1: Integration within Units or Simulators

This MOE measures the effectiveness of the proposed system to integrate units of a strike group with other units, or to integrate simulators with other simulators. It is not intended to measure a simulator's ability to integrate with a unit.

b. MOE 4.2: Integration between Units and Simulators

This MOE is designed to measure the effectiveness of a unit to integrate with a simulator. All units composing a strike group are to be considered, as are all simulators used across the communities.

c. MOE 4.3: Integration at Sea

This MOE measures how well units integrate with each other at sea for training simulations. This considers units at sea in coastal regions where they may be stimulated from shore facility antennas as well as units far out to sea, such as crossing an ocean on the way to or from deployment.

d. MOE 4.4: Integration at Sea with In-Port Units

This MOE captures how well strike group units out to sea can integrate with units that remain in port. It is not always feasible to have all units designated to participate in a particular training exercise together in port or together out to sea. If the system can integrate units at sea with units in port, this would alleviate that constraint.

e. MOE 4.5: Integration in Port

This MOE measures the effectiveness of the strike group to conduct integrated training scenarios in port, similar to the FST events conducted today.

5. COI 5 – How Well Does the System Implement the Principles of High-Velocity Learning?

The weapon systems wielded on the battlefield today are more complex than ever before and so is the training associated with employing those weapon systems. It is of vital importance to train better and more quickly to stay ahead of a potential adversary. This COI addresses how well the proposed training system achieves the principles of high-velocity learning.

a. MOE 5.1: Fidelity

This MOE captures the fidelity of the training taking place. It is intended to capture all aspects of fidelity, including the fidelity of the weapons and tactics employed, the fidelity of enemy responses to warfighter actions, and the fidelity of the console or simulator used to provide the training.

b. MOE 5.2: Repetition

This MOE captures the ease of repetition of a proposed training architecture. During stakeholder engagement and from personal experience, the team identified a lack of repetition when it comes to training, particularly integrated training at the strike group level. The Repetition MOE will capture how easy it is for a particular training simulation to be repeated multiple times based on the anticipated time commitment, number of players involved, access to the required hardware or software, and depending on how the training simulation is controlled.

c. MOE 5.3: Retention

This MOE measures how well a warfighter or unit is expected to retain the information and experience learned during training simulations. Retention is thought to be a function of the number of times a training is conducted and the level of fidelity for that training. While this is a qualitative assessment, it is thought that repetition will have a larger impact than fidelity with regard to retention.

F. OVERALL MEASURE OF EFFECTIVENESS

The Overall Measure of Effectiveness (OMOE) is a means of assessing the performance of alternative systems in an analysis of alternatives. The OMOE process starts with engineers determining the MOEs by a system can be evaluated, then they determine the Measures of Performance (MOP) for each MOE, and then the key performance parameters that are used to measure those MOPs (Parnell, Driscoll and Henderson 2010).

The following discussion and approach to swing weights follows the process as laid out in Parnell, Driscoll, and Henderson's, *Decision Making in Systems Engineering and Management*. While all MOEs and MOPs are important, some are more important to mission accomplishment than others and should be weighted more significantly. In order to account for this, the team used a swing weight matrix to rank the importance of MOEs in relation to each other. Once the ranking relationship of the MOEs is determined a normalized weighted value on a scale of zero to one can be determined to account for these MOEs' importance (Parnell, Driscoll and Henderson 2010).

Since the WFTS is a broad architectural concept being evaluated as a qualitative assessment, specific performance numbers associated with evaluating MOPs would convey little value. Therefore, the team makes a qualitative assessment of how well each alternative is expected to perform the MOEs. The qualitative assessment will be normalized as a value ranging from zero to one.

Once the normalized swing weights and normalized values for the MOEs have been determined, the OMOE value can be determined using Equation 1, where $V(\mathbf{x})$ is the OMOE for design alternative \mathbf{x} , w_i is the normalized swing weight for a particular MOE, and $v(x_i)$ is the MOE qualitative normalized value for design option \mathbf{x} with respect to each particular MOE (Parnell, Driscoll and Henderson 2010, 295).

$$V(\mathbf{x}) = \sum_{i=1}^n w_i v(x_i) \quad (Eq. 1)$$

The sum product of these two values results in an OMOE value scaled between zero and one for each design alternative. These OMOE values may then be directly compared across the design alternatives to determine which design was assessed to have the highest performance.

G. DETERMINATION OF SWING WEIGHTS

In order to determine a normalized weight, the team had to qualitatively assess each MOE on two qualities. The first was how large a capability gap is the MOE assessing, and the second is how important is the MOE to the mission. The capability gap assessment was then broken into three sub-categories: low, medium, and high. The level of importance was also broken into three categories: mission critical, mission effective, and mission enhancing. This breakdown is shown in Table 19.

Table 19. Swing Weight Identification Matrix

| | | Level of Importance | | |
|----------------|--------|---------------------|-------------------|-------------------|
| | | Mission Critical | Mission Effective | Mission Enhancing |
| Capability Gap | High | A | C | F |
| | Medium | B | E | H |
| | Low | D | G | I |

Derived from Parnell, Driscoll and Henderson 2010, 299.

The lettering system in Table 19 indicates the cells labeled with lower alphabetic letters are more important than the other cells that have higher alphabetic letters. In other words, A>B>C and so forth. If multiple MOEs are put into a given cell, then the MOE at the top of the cell is weighted as more important than or equal to the ones listed below it.

Once all the MOEs have been assigned a proper location in the table, and using the alphabetic ranking system, we can assign each MOE a non-normalized value. Once each MOE has a value, those values can then be normalized to a value between zero and one using Equation 2, where f_i is the non-normalized swing weight for a particular MOE that the team assigned in Table 20 (Parnell, Driscoll, and Henderson 2010, 298).

$$w_i = \frac{f_i}{\sum_{i=1}^n f_i} \quad (Eq. 2)$$

Table 20 shows each MOE that the team identified and the non-normalized swing weight ranking of each MOE in reference to the Table 19. The normalized swing weight values for all the MOEs found using Equation 2 are presented in Table 21.

Table 20. WFTS Non-Normalized Swing Weight Matrix

| | | Level of Importance | | | | | |
|----------------|--------|---------------------|-------|-----------------------|-------|-------------------|-------|
| | | Mission Critical | | Mission Effectiveness | | Mission Enhancing | |
| | | MOE | Score | MOE | Score | MOE | Score |
| Capability Gap | Large | 1.1 | 99 | 5.2 | 79 | 3.1 | 45 |
| | | 1.3 | 98 | 4.3 | 78 | | |
| | | | | 4.2 | 73 | | |
| | | | | 4.4 | 70 | | |
| | Medium | 5.3 | 88 | 2.2 | 58 | | |
| | | 5.1 | 84 | 4.1 | 56 | | |
| | Small | 1.2 | 65 | 2.3 | 38 | 2.1 | 19 |
| | | | | 4.5 | 31 | | |

Table 21. WFTS Normalized Swing Weight Matrix

| | | Level of Importance | | | | | |
|----------------|--------|---------------------|-------|-----------------------|-------|-------------------|-------|
| | | Mission Critical | | Mission Effectiveness | | Mission Enhancing | |
| | | MOE | Score | MOE | Score | MOE | Score |
| Capability Gap | Large | 1.1 | 0.101 | 5.2 | 0.081 | 3.1 | 0.046 |
| | | 1.3 | 0.100 | 4.3 | 0.080 | | |
| | | | | 4.2 | 0.074 | | |
| | | | | 4.4 | 0.071 | | |
| | Medium | 5.3 | 0.090 | 2.2 | 0.059 | | |
| | | 5.1 | 0.086 | 4.1 | 0.057 | | |
| | Small | 1.2 | 0.066 | 2.3 | 0.039 | 2.1 | 0.019 |
| | | | | 4.5 | 0.032 | | |

H. DETERMINATION OF QUALITATIVE VALUES FOR MOES

Each MOE for each alternative is based upon a qualitative scale in order to determine the value of the MOE to be used in the OMOE process. Table 22 shows the qualitative scale that the team used. Table 23 shows the non-normalized MOE values, and Table 24 shows the normalized MOE values.

Table 22. MOE Assessment Scale

| Assessment Scale | Value | Normalized Value |
|------------------------|-------|------------------|
| Does not Meet MOE | 0 | 0 |
| Partially Meets MOE | 1 | 0.25 |
| Fully Meets MOE | 2 | 0.5 |
| Moderately Exceeds MOE | 3 | 0.75 |
| Greatly Exceeds MOE | 4 | 1 |

Table 23. Non-Normalized MOE Values

| MOE | | Weight | Design Alternative | | | | | | | | |
|-----|--|--------|--------------------|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1.1 | Fits into basic phase | 0.101 | 4 | 2 | 2 | 2 | 2 | 0 | 0 | 4 | 2 |
| 1.2 | Fits into integrated phase | 0.066 | 4 | 3 | 3 | 3 | 2 | 2 | 3 | 0 | 0 |
| 1.3 | Fits into sustainment phase | 0.100 | 4 | 2 | 2 | 3 | 2 | 2 | 0 | 2 | 2 |
| 2.1 | Scenario management | 0.019 | 1 | 2 | 3 | 3 | 2 | 3 | 1 | 4 | 4 |
| 2.2 | Understanding enemy | 0.059 | 4 | 3 | 3 | 3 | 3 | 3 | 2 | 1 | 1 |
| 2.3 | Identify warfighter decisions | 0.039 | 4 | 3 | 3 | 3 | 3 | 3 | 2 | 1 | 3 |
| 3.1 | Automation of data processing | 0.046 | 4 | 3 | 2 | 3 | 2 | 2 | 0 | 2 | 2 |
| 4.1 | Integration within units or simulators | 0.057 | 4 | 4 | 4 | 4 | 2 | 4 | 3 | 0 | 0 |
| 4.2 | Integration between units and simulators | 0.074 | 4 | 4 | 0 | 0 | 3 | 0 | 1 | 0 | 0 |
| 4.3 | Integration at sea | 0.080 | 4 | 4 | 4 | 4 | 0 | 4 | 2 | 0 | 0 |
| 4.4 | Integration at sea with in port unit | 0.071 | 4 | 0 | 4 | 0 | 0 | 0 | 2 | 0 | 0 |
| 4.5 | Integration in port | 0.032 | 4 | 0 | 4 | 0 | 4 | 0 | 3 | 0 | 0 |
| 5.1 | Fidelity | 0.086 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 1 | 2 |
| 5.2 | Repetition | 0.081 | 3 | 3 | 2 | 3 | 3 | 3 | 1 | 4 | 4 |
| 5.3 | Retention | 0.090 | 3 | 3 | 2 | 3 | 3 | 3 | 2 | 3 | 3 |

Table 24. Normalized MOE Values

| MOE | | Weight | Design Alternative | | | | | | | | |
|-----|--|--------|--------------------|------|------|------|------|------|------|------|------|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1.1 | Fits into basic phase | 0.101 | 1 | 0.5 | 0.5 | 0.5 | 0.5 | 0 | 0 | 1 | 0.5 |
| 1.2 | Fits into integrated phase | 0.066 | 1 | 0.75 | 0.75 | 0.75 | 0.5 | 0.5 | 0.75 | 0 | 0 |
| 1.3 | Fits into sustainment phase | 0.100 | 1 | 0.5 | 0.5 | 0.75 | 0.5 | 0.5 | 0 | 0.5 | 0.5 |
| 2.1 | Scenario management | 0.019 | 0.25 | 0.5 | 0.75 | 0.75 | 0.5 | 0.75 | 0.25 | 1 | 1 |
| 2.2 | Understanding enemy | 0.059 | 1 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.5 | 0.25 | 0.25 |
| 2.3 | Identify warfighter decisions | 0.039 | 1 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.5 | 0.25 | 0.75 |
| 3.1 | Automation of data processing | 0.046 | 1 | 0.75 | 0.5 | 0.75 | 0.5 | 0.5 | 0 | 0.5 | 0.5 |
| 4.1 | Integration within units or simulators | 0.057 | 1 | 1 | 1 | 1 | 0.5 | 1 | 0.75 | 0 | 0 |
| 4.2 | Integration between units and simulators | 0.074 | 1 | 1 | 0 | 0 | 0.75 | 0 | 0.25 | 0 | 0 |
| 4.3 | Integration at sea | 0.080 | 1 | 1 | 1 | 1 | 0 | 1 | 0.5 | 0 | 0 |
| 4.4 | Integration at sea with in port unit | 0.071 | 1 | 0 | 1 | 0 | 0 | 0 | 0.5 | 0 | 0 |
| 4.5 | Integration in port | 0.032 | 1 | 0 | 1 | 0 | 1 | 0 | 0.75 | 0 | 0 |
| 5.1 | Fidelity | 0.086 | 1 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.25 | 0.5 |
| 5.2 | Repetition | 0.081 | 0.75 | 0.75 | 0.5 | 0.75 | 0.75 | 0.75 | 0.25 | 1 | 1 |
| 5.3 | Retention | 0.090 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

I. OMOE FOR ALL DESIGN ALTERNATIVES

Now that the values of each MOE for each alternative and the normalized swing weights have been determined, the OMOE for all the design alternatives can be determined using Equation 1, where the OMOE is the sum product of the normalized weighted values and the normalized qualitative value of the MOE. Table 25 shows the results of the OMOE analysis.

Table 25. OMOE Values for Each Design Alternative

| Design Alternative | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|--------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| OMOE Value | 0.9429 | 0.6705 | 0.6498 | 0.6259 | 0.5474 | 0.5224 | 0.3932 | 0.3869 | 0.3772 |

The design alternatives are listed again here for convenience.

1. Fully capable system addresses all major capability gaps identified.
2. Strike group out to sea integrated with a shore based simulator network.
3. A ship out to sea integrated with a ship in port.
4. A squadron of similar units integrating for training out to sea.
5. Ships in port integrating with a shore based simulator.
6. A strike group conducting sustainment training at sea.
7. Fleet synthetic training exercise integrating in port or at sea units during the integrated phase.
8. Low fidelity trainer integrating units at sea and in port.
9. Single unit in port being fed a scenario from a local training center.

Table 25 indicates that DA1 had the highest training value as determined by its OMOE, while DA9 had the lowest training value. It should be expected that DA1 has the highest value as this system was designed to allow for webfires training under all anticipated conditions and during all phases of the OFRP.

The purpose in determining the OMOE for each design alternative is to determine which alternative had the best score and to allow for comparisons between alternatives. The real value of Table 25 is that it shows the relative scores of the different design alternatives and how they compare. Design alternatives two, three, and four were all very comparable in training value, while alternatives five and six were grouped close together, and finally seven, eight, and nine were grouped close together.

Additionally, if a decision maker were to determine they do not need all of the capabilities provided in DA1, or the budget does not support DA1, that decision maker could look at the other alternatives and choose a lower cost option with less capability. The OMOE values provide an indication of the abstract potential value of the WFTS that is gained or lost depending on the design alternative chosen.

As a budget is not available for consideration, and the costs of these design alternatives are not being considered, the natural recommendation is to move forward

with DA1. It is important to note that the OMOEs calculated in Table 25 are the result of the weights and scores determined by the team after consultation with stakeholders. Individual stakeholders may regard each MOE with a different weight, or assess an alternative's performance in that MOE differently. To explore the possible impact of changing the weights on the OMOE values, a sensitivity analysis was conducted. This process will be discussed in the following section.

J. SENSITIVITY ANALYSIS PROCESS

The identification of the swing weights above is subjective, therefore, the ranking of alternatives may be sensitive to variations in the weighted value resulting in one alternative's OMOE being higher than another. It is important to perform sensitivity analysis to show the stakeholder that while a particular alternative may have a higher OMOE based on the current assessment scale, minor changes in preference could result in different alternatives having higher OMOE values. This can then be used to aid in determining the most appropriate design alternative and help inform decision makers about potential risk and uncertainty.

In order to determine the sensitivity of a particular swing weight the following information needs to be determined, as shown in Table 26.

Table 26. Information for Sensitivity Analysis

| Information | Description |
|-------------|---|
| Y_1 | Current OMOE value for Alternative |
| Y_2 | Normalized MOE value for associated Swing Weight being assessed |
| X_1 | Normalized Swing Weight value for MOE being assessed |
| X_2 | Value is 1 |

Table 27 shows the calculations performed for DA1. This information will be used to aid the reader in understanding how sensitivity analysis was performed. The same calculations were repeated for each design alternative.

Table 27. Sensitivity Analysis Calculations for DA1

| MOEs | | Normalized Swing Weight (w_i) | Option | |
|------|--|--|---------------------------|---------------------------------|
| | | | MOE value (v_i) | Product ($W_i \times v_i$) |
| 1.1 | Fits into Basic Phase | 0.101 | 1 | 0.1009 |
| 1.2 | Fits into Integrated | 0.066 | 1 | 0.0663 |
| 1.3 | Fits into Sustainment | 0.100 | 1 | 0.0999 |
| 2.1 | Scenario Management | 0.019 | 0.25 | 0.0048 |
| 2.2 | Understanding Enemy | 0.059 | 1 | 0.0591 |
| 2.3 | Identify warfighter decisions | 0.039 | 1 | 0.0387 |
| 3.1 | Automation of Data Processing | 0.046 | 1 | 0.0459 |
| 4.1 | Integration within units or simulators | 0.057 | 1 | 0.0571 |
| 4.2 | Integration between units and simulators | 0.074 | 1 | 0.0744 |
| 4.3 | Integration at sea | 0.080 | 1 | 0.0795 |
| 4.4 | Integration at sea with in port unit | 0.071 | 1 | 0.0714 |
| 4.5 | Integration in Port | 0.032 | 1 | 0.0316 |
| 5.1 | Fidelity | 0.086 | 1 | 0.0856 |
| 5.2 | Repetition | 0.081 | 0.75 | 0.0604 |
| 5.3 | Retention | 0.090 | 0.75 | 0.0673 |
| | | | OMOE Option | 0.9429 |

Using the sample data from Table 27, Table 28 will show the sensitivity data needed for sensitivity analysis.

Table 28. Sample Data for Sensitivity Analysis of MOE 1.1

| Information | Sample Data |
|-------------|-------------|
| Y_1 | .9429 |
| Y_2 | 1 |
| X_1 | 0.101 |
| X_2 | 1 |

Using the equation for the determination of the slope of a linear line and the equation for a linear line; the slope and y-intercept can be determined and plotted on a

graph. This process is repeated for each design alternative and can then be plotted as shown in Figure 38.

Once the equations for all the other design alternatives have been determined and plotted, the team can then see if these lines cross. The value for a particular swing weight that would result in an alternative being chosen over another alternative can be observed at the intersections of lines. That swing weight value can be calculated by taking the equation of two lines that cross, setting them equal to each other, and then solving for the swing weight value using algebra.

The next section of this report will show the results of the team's sensitivity analysis. Although all MOES were analyzed, only the relevant MOEs that are sensitive will be discussed below.

K. SENSITIVITY ANALYSIS RESULTS

Sensitivity analysis was conducted for the top four design alternatives, DA1 through DA4, using spreadsheet software. There were a total of eight instances where changing the swing weights would change the order of the OMOEs, and only one of those instances where DA1 was no longer the highest OMOE. Each of those instances will be discussed in more detail according to the affected MOE weights.

1. MOE 1.3 Fits into Sustainment Phase

For all MOE 1.3 weights, DA1 remains the preferred design, but the order of some of the other designs change as the MOE weight changes. The current weight for MOE 1.3 is 0.102. DA3 is dominated by DA4 once the weight increases to 0.18, while DA2 is then dominated by DA4 for MOE 1.3 weights greater than 0.24. Figure 38 shows the impact of MOE 1.3 weight on the first four design alternatives.

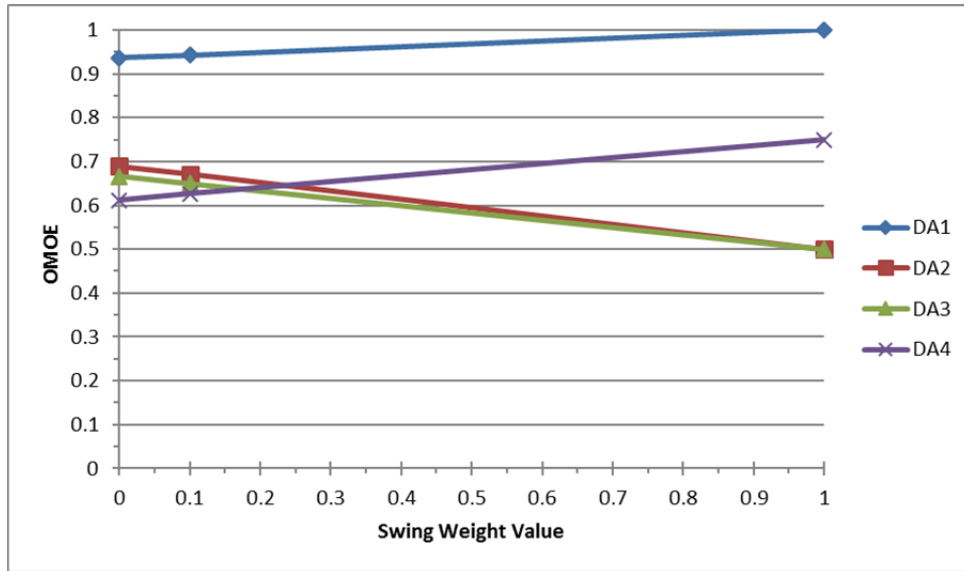


Figure 38. MOE 1.3 Sensitivity Analysis

2. MOE 2.1 Scenario Management

This is the only weight where DA1 does not always dominate the other designs. The current weight for MOE 2.1 is 0.020. If this weight is increased beyond 0.38 DA1 becomes dominated by DA3, with DA3 remaining the preferred design. Figure 39 shows the impact of MOE 2.1 weight on the first four design alternatives.

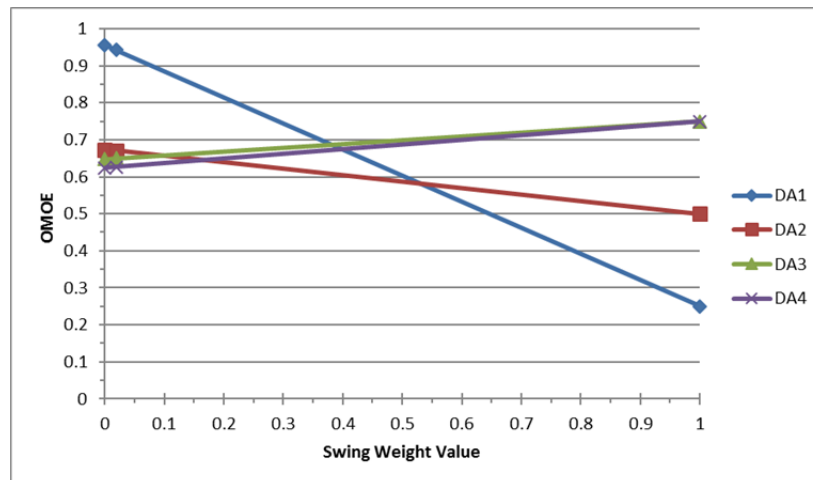


Figure 39. MOE 2.1 Sensitivity Analysis

3. MOE 3.1 Automation of Data Processing

For all MOE 3.1 weights, DA1 remains the preferred design, but the order of some of the other designs change as the MOE weight changes. The current weight for MOE 3.1 is 0.036. DA3 is dominated by DA4 once the weight increases to 0.13. Figure 40 shows the impact of MOE 3.1 weight on the first four design alternatives.

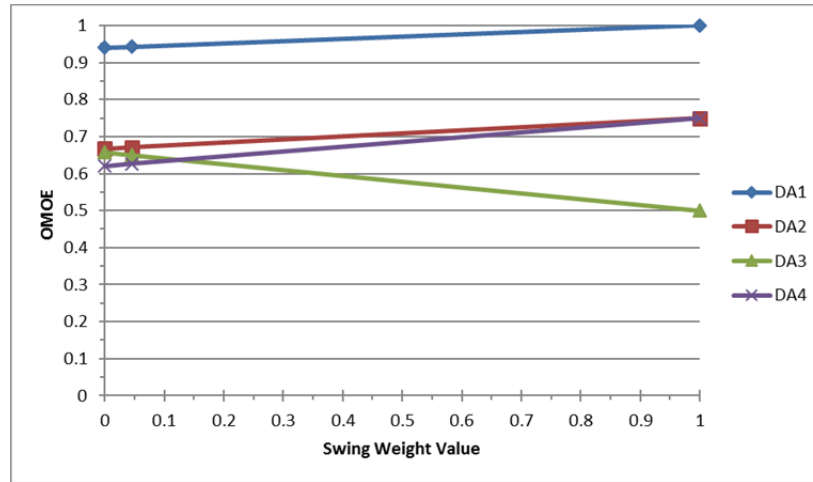


Figure 40. MOE 3.1 Sensitivity Analysis

4. MOE 4.2 Integration between Units and Simulators

For all MOE 4.2 weights, DA1 remains the preferred design, but the order of some of the other designs change as the MOE weight changes. The current weight for MOE 4.2 is 0.066. DA4 is dominated by DA2 once the weight increases to 0.03, while DA3 is then dominated by DA2 for MOE 4.2 weights greater than 0.05. Figure 41 shows the impact of MOE 4.2 weight on the first four design alternatives.

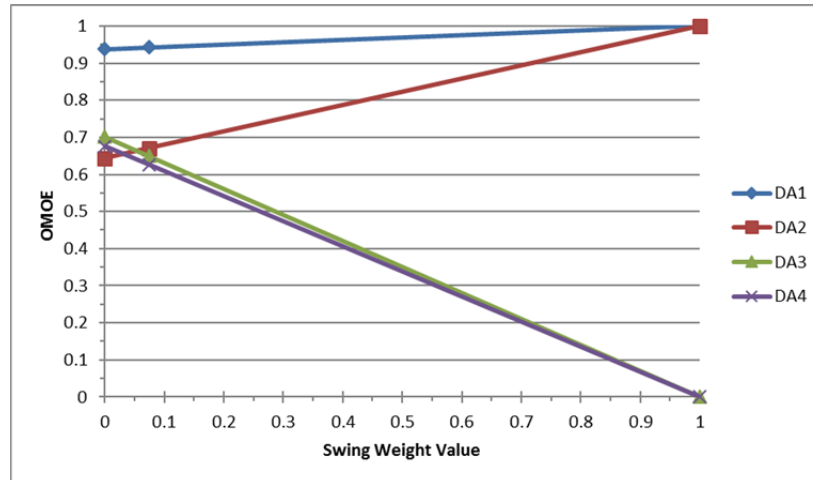


Figure 41. MOE 4.2 Sensitivity Analysis

5. MOE 4.4 Integration at sea with in Port Unit

For all MOE 4.4 weights, DA1 remains the preferred design, but the order of some of the other designs change as the MOE weight changes. The current weight for MOE 4.4 is 0.066. DA4 is dominated by DA3 once the weight increases to 0.05, while DA2 is then dominated by DA3 for MOE 4.4 weights greater than 0.09. Figure 42 shows the impact of MOE 4.4 weight on the first four design alternatives.

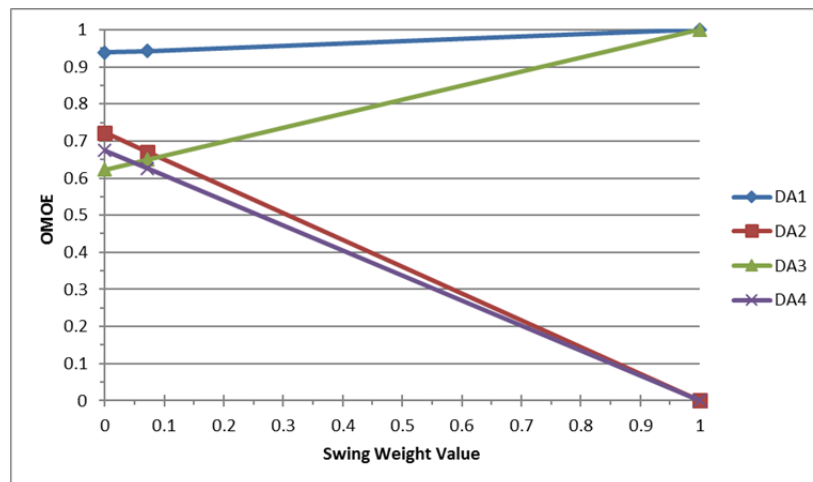


Figure 42. MOE 4.4 Sensitivity Analysis

6. MOE 4.5 Integration in Port

For all MOE 4.5 weights, DA1 remains the preferred design, but the order of some of the other designs change as the MOE weight changes. The current weight for MOE 4.5 is 0.043. DA4 is dominated by DA3 once the weight increases to 0.008, while DA2 is then dominated by DA3 for MOE 4.5 weights greater than 0.05. Figure 43 shows the impact of MOE 4.5 weight on the first four design alternatives.

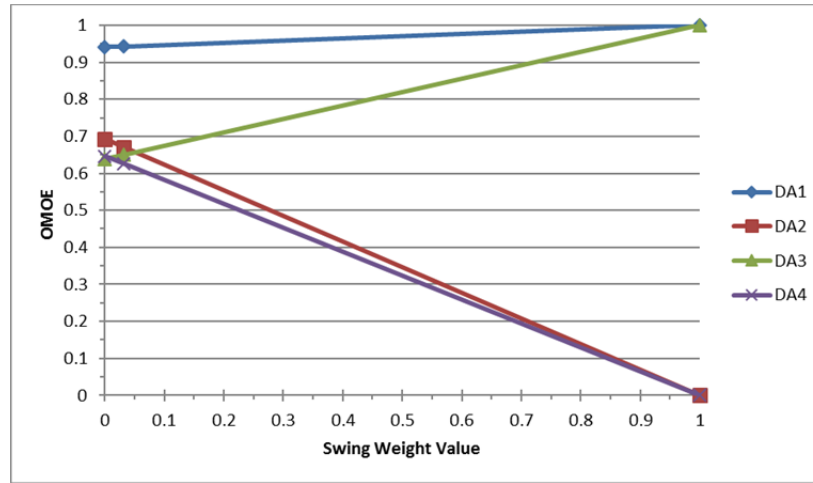


Figure 43. MOE 4.5 Sensitivity Analysis

7. MOE 5.2 Repetition

For all MOE 5.2 weights, DA1 remains the preferred design, but the order of some of the other designs change as the MOE weight changes. The current weight for MOE 5.2 is 0.072. DA3 is dominated by DA4 for all weights greater than 0.16. Figure 44 shows the impact of MOE 5.2 weight on the first four design alternatives.

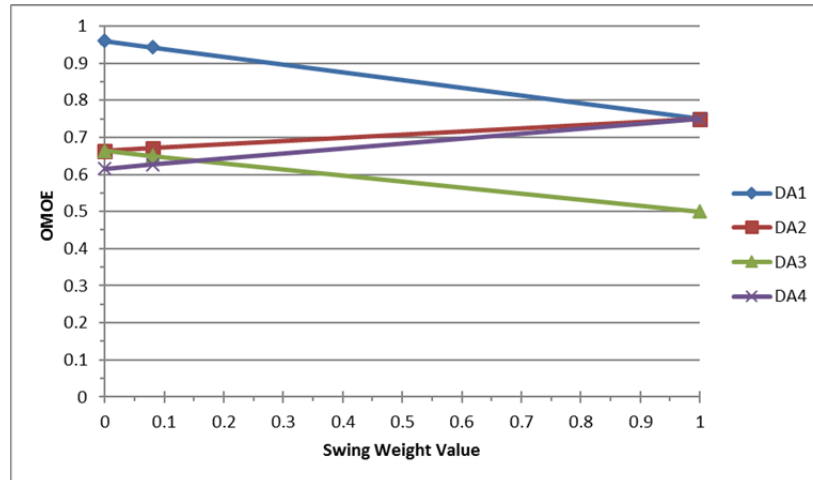


Figure 44. MOE 5.2 Sensitivity Analysis

8. MOE 5.3 Retention

For all MOE 5.3 weights, DA1 remains the preferred design, but the order of some of the other designs change as the MOE weight changes. The current weight for MOE 5.3 is 0.092. DA3 is dominated by DA4 for all weights greater than 0.17. Figure 45 shows the impact of MOE 5.3 weight on the first four design alternatives.

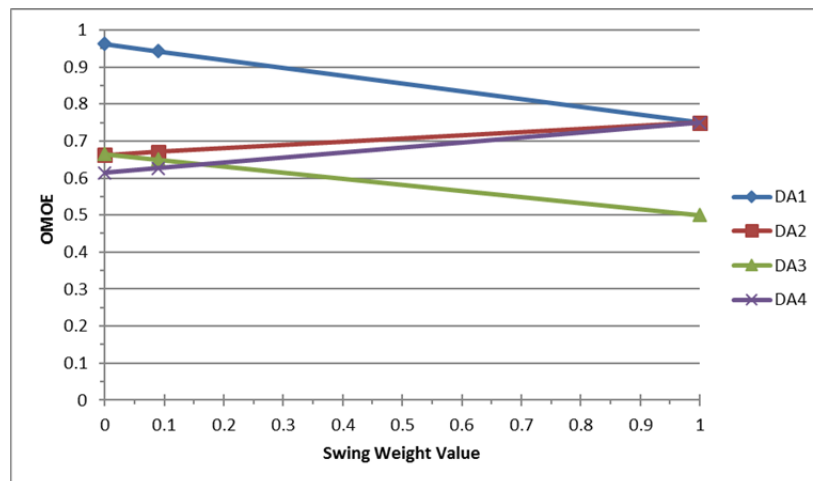


Figure 45. MOE 5.3 Sensitivity Analysis

X. SYSTEM ARCHITECTURE

System architecture is a means of conveying the complexity of a system in ways that can show its properties, relationships, and behaviors from different viewpoints (DOD Deputy Chief Information Officer 2017a). The process is similar to traditional architecture, where an architect will create multiple blue prints or drawings to describe a structure. To further the example, one blueprint may be an illustration that shows the architecturally significant aspects of a structure to a customer financing a house, while another blueprint for the general contractor may be more detailed, showing the home's electrical wiring plan. In both architecture and systems engineering, there is a need for multiple views that must be modeled from different perspectives in order to design and build a complex system.

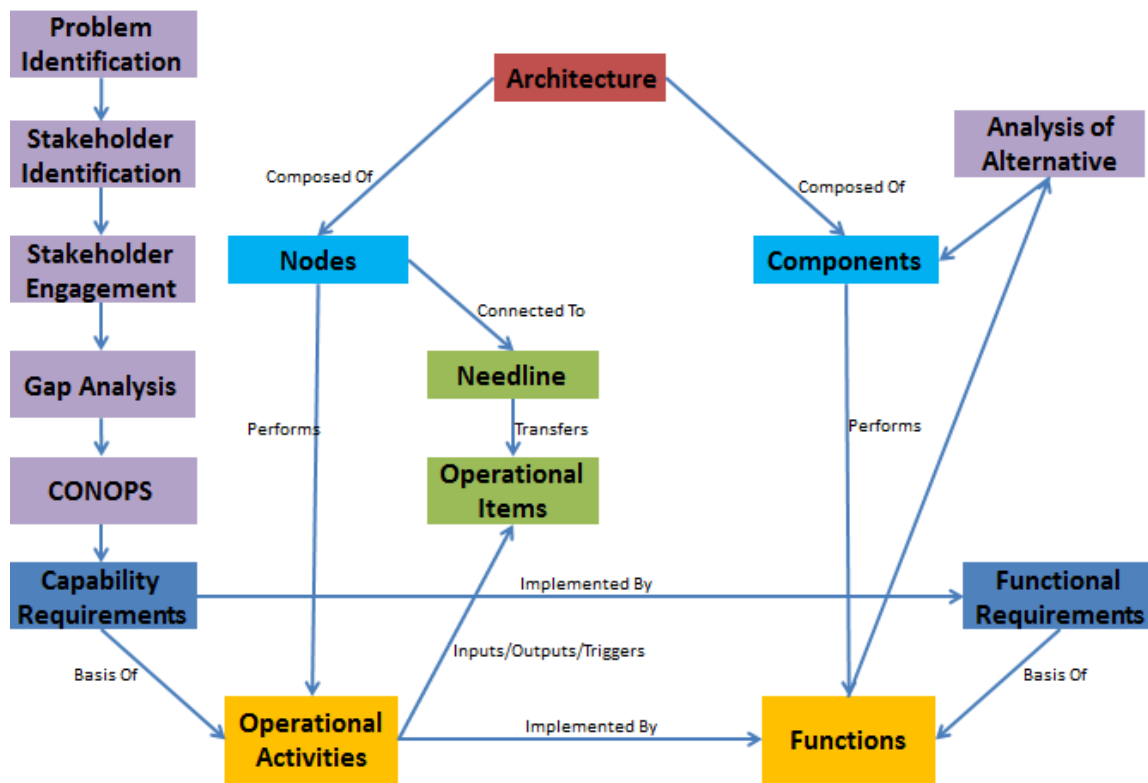
For the purpose of this report, the DOD Architectural Framework (DoDAF) will be used to depict these viewpoints. The DoDAF is the standard used by the DOD and will allow for common understanding. Some non-DoDAF tools have been incorporated in the following discussion to show views of the system that are important but have no corresponding standard DoDAF view.

A. ARCHITECTURAL OVERVIEW

The team completed the process of problem identification, stakeholder identification, gap analysis, and CONOPS generation that enabled the determination of capabilities requirements. The WFTS needs to fill the capability gaps that were determined through research and stakeholder engagement. The capabilities requirements allowed for the determination of operational activities (organizational functions) that must be performed by the nodes (organizations). After nodes (organizations) and operational activities were determined, the operational items (information passing between organizational functions) were determined. This then allowed for needlines (communication pathways between nodes) to be determined to support the exchange of operational items. After all of these were determined, the team could then identify the functions and functional requirements that components (hardware/software) would have

to meet in order to support the operational activities and meet the capabilities requirements of the system. Finally, using an analysis of alternatives approach, the team determined a final design of components that would best fulfill the capability requirements of the system.

The organizations, components, requirements, and functions (people and system) and their inter-relationships that are necessary to fill the capability gaps are shown in Figure 46. They are discussed in greater detail throughout this chapter.



Adapted from CORE Architecture Definition Guide (DoDAF v2.02).

Figure 46. WFTS Architectural Overview

B. ARCHITECTURAL VIEWPOINTS

The success of any system depends on the foundation provided to design, implement, support, and potentially build upon, improve, or expand that system. This creates a synergistic relationship that converts raw material and data entering a well-

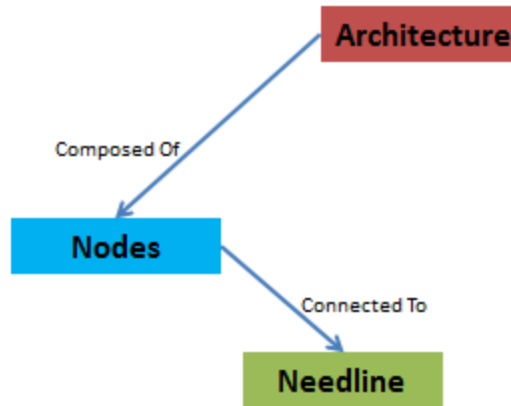
designed system into a viable end-product that meets or exceeds customer needs and requirements. The viewpoints that are used to show the relationships are described briefly in Table 26.

Table 29. Architectural Viewpoints

| View Point | Description |
|--|--|
| Operational Resource Flow Description (OV-2) | Shows the nodes (organizations) and the needlines (communication connections) between other nodes. |
| Operational Items Transfer Matrix | Shows the operational items (information) that is being passed along each needline that connects each node. |
| State Transition Description (OV-6b) | Shows the sequencing of the operational activities. |
| Operational Activity Model (OV-5b) | Shows the nodes, operational activities that they perform, and the operational items that are being passed between operational activities. |
| Capability to Operation Activity Mapping (CV-6) | Shows the capabilities that each operational activity is supporting. |
| Operational Activity to Systems Function Traceability Matrix (SV-5a) | Shows the functions of the system that implement/support the operational activities. |
| Functions to Systems Traceability Matrix | Shows what components comprise the system, what functions each component performs, and what operational activity it supports when combined with the SV-5a. |
| Capability Requirements to Functional Requirements Traceability Matrix | Shows the mapping between functional requirements and capability requirements. |
| Functional Requirements to Functions Traceability Matrix | Shows the mapping between functions and functional requirements. |

1. Operational Resource Flow Description for Webfires Training (OV-2)

This section shows the nodes (or organizations) that make up the WFTS and the needlines that connect these organizations. The relationship that this architectural view is focusing on in relation to the architectural overview in Section A is shown in Figure 47.



Adapted from CORE Architecture Definition Guide (DoDAF v2.02).

Figure 47. OV-2 Relationship to Overall System Architecture

According to DoDAF Version 2.02:

The OV-2 can be used to show flows of funding, personnel and materiel in addition to information. A specific application of the OV-2 is to describe a logical pattern of resource (information, funding, personnel, or materiel) flows. The logical pattern need not correspond to specific organizations, systems or locations, allowing Resource Flows to be established without prescribing the way that the Resource Flows are handled and without prescribing solutions.

The intended usage of the OV-2 includes:

- Definition of operational concepts.
- Elaboration of capability requirements.
- Definition of collaboration needs.
- Applying a local context to a capability.
- Problem space definition.
- Operational planning.
- Supply chain analysis.
- Allocation of activities to resources. (DOD Deputy Chief Information Officer 2017c)

Figure 48 shows the organizations that are involved in the WFTS, which organizations pass information between each other, and the general information passed

between them. Each needline represents information flow and can be either an input, output, or both (represented by the directional arrows) from individual organizations.

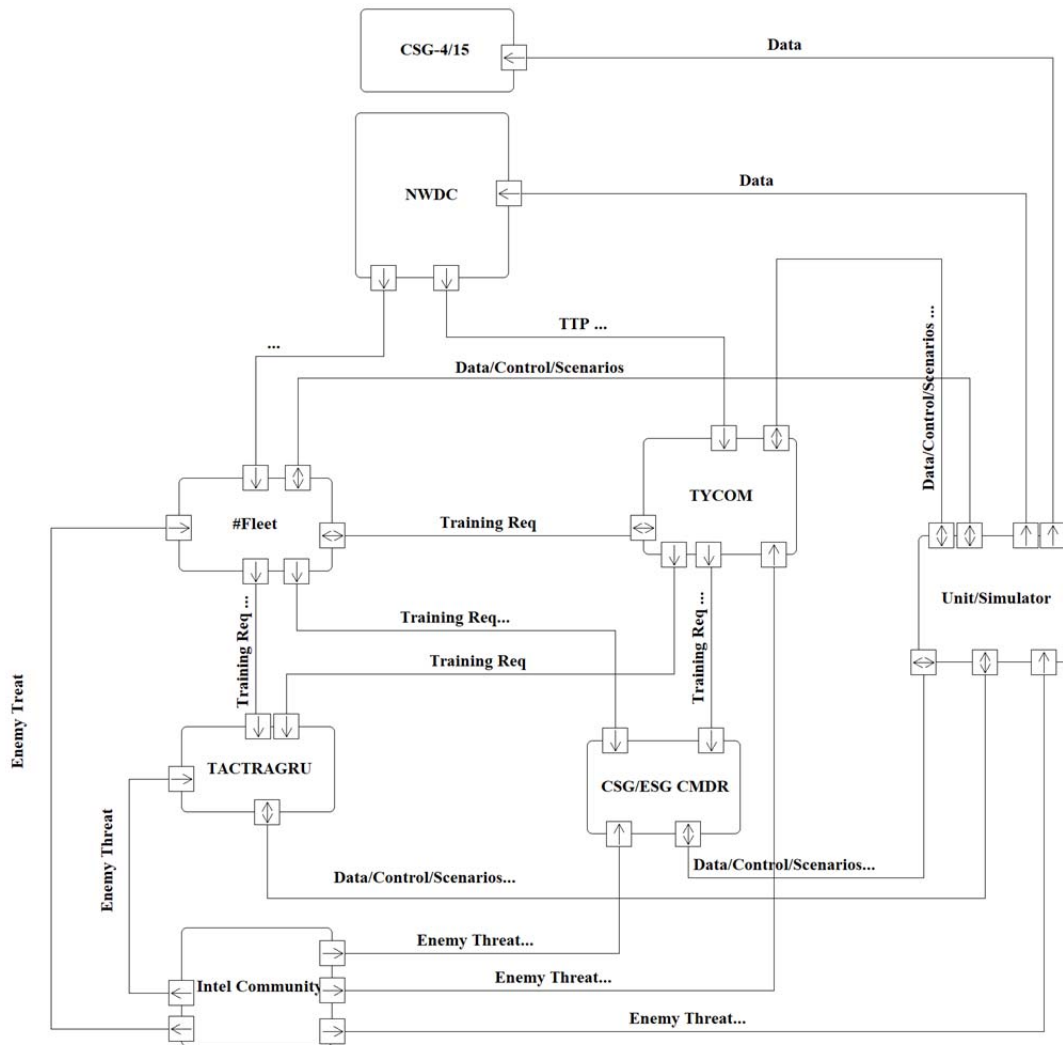


Figure 48. WFTS OV-2

2. Operational Items Transfer Matrix

The Operational Items Transfer Matrix, as shown in Appendix D, Section A, describes in more detail what nodes are connecting to each other and exactly what each node is exchanging with the other. This matrix, along with the OV-2, can aid the reader

in understanding what and how the organizations can communicate in order to meet the capability requirements.

3. State Transition Description (OV-6b)

According to DoDAF Version 2.02:

The OV-6b is a graphical method of describing how an operational activity responds to various events by changing its state.

The intended usage of the OV-6b includes:

- Analysis of business events.
- Behavioral analysis.
- Identification of constraints. (DOD Deputy Chief Information Officer 2017e)

Figure 49 shows the three different states or phases (Support Training, Conduct Training, and Evaluate Training) that the WFTS operates under in order to provide training. Each one of these phases has different operational activities associated with it and has different organizations that are involved in each. The figure also shows that this is an iterative loop that is completed multiple times to support all phases of the OFRP. This section discusses each one of the phases in more detail.

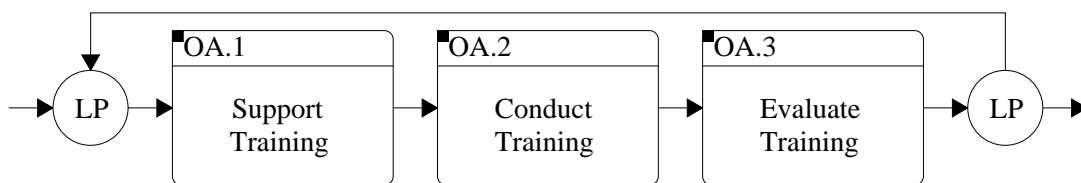
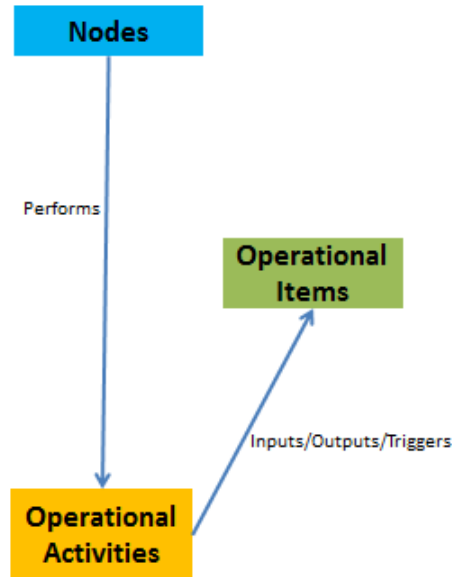


Figure 49. WFTS State Diagram (OV6b)

4. Operational Activity Model (OV-5b)

Figure 50 shows the relationship that the OV-5b has to the architectural overview in Section A. An OV-5b is shown for each one of the operational activities shown in Figure 49. Each OV-5b shows the nodes (Organizations) that are involved in that phase,

what operational activities they perform, and the Operational Items that are shared between the operational activities.



Adapted from CORE Architecture Definition Guide (DoDAF v2.02)

Figure 50. OV-5b Relationship to Architectural Overview

According to DoDAF Version 2.02:

The OV-5a and the OV-5b describe the operations that are normally conducted in the course of achieving a mission or a business goal. It describes operational activities (or tasks); Input/ Output flows between activities, and to/from activities that are outside the scope of the Architectural Description.

The OV-5a and OV-5b describes the operational activities that are being conducted within the mission or scenario. The OV-5a and OV-5b can be used to:

- Clearly delineate lines of responsibility for activities when coupled with OV-2.
- Uncover unnecessary operational activity redundancy.
- Make decisions about streamlining, combining, or omitting activities.

- Define or flag issues, opportunities, or operational activities and their interactions (information flows among the activities) that need to be scrutinized further.

The intended usage of the OV-5a and OV-5b includes:

- Description of activities and workflows.
- Requirements capture.
- Definition of roles and responsibilities.
- Support task analysis to determine training needs.
- Problem space definition.
- Operational planning.
- Logistic support analysis.
- Information flow analysis. (DOD Deputy Chief Information Officer 2017d)

How to Read Figure 51, Figure 52, and Figure 53:

Each parallel line represents a node. Along those lines are boxes that represent the operational activities that those nodes perform. Passing between those operational activities are operational items. The arrows indicate the flow of operational items from one operational activity to the next and show the operational activities that must be accomplished prior to the next operational activity.

Figure 51 shows the operational activities that the Intelligence Community, Numbered Fleet, TACTRAGRU, TYCOM, NWDC, and CSG/ESG CMDR perform during the Support Training phase of the WFTS. During this phase, NWDC develops TTPs that are then passed to the numbered fleet and TYCOM. Additionally, the intelligence community will pass intelligence to the other organizations. TACTRAGRU, TYCOM, Numbered Fleet, and the CSG/ESG CMDR can then create different training scenarios (simulations) for Units, Simulators, or Strike Groups that fit into the Basic, Integrated, and Sustainment Phases of the OFRP.

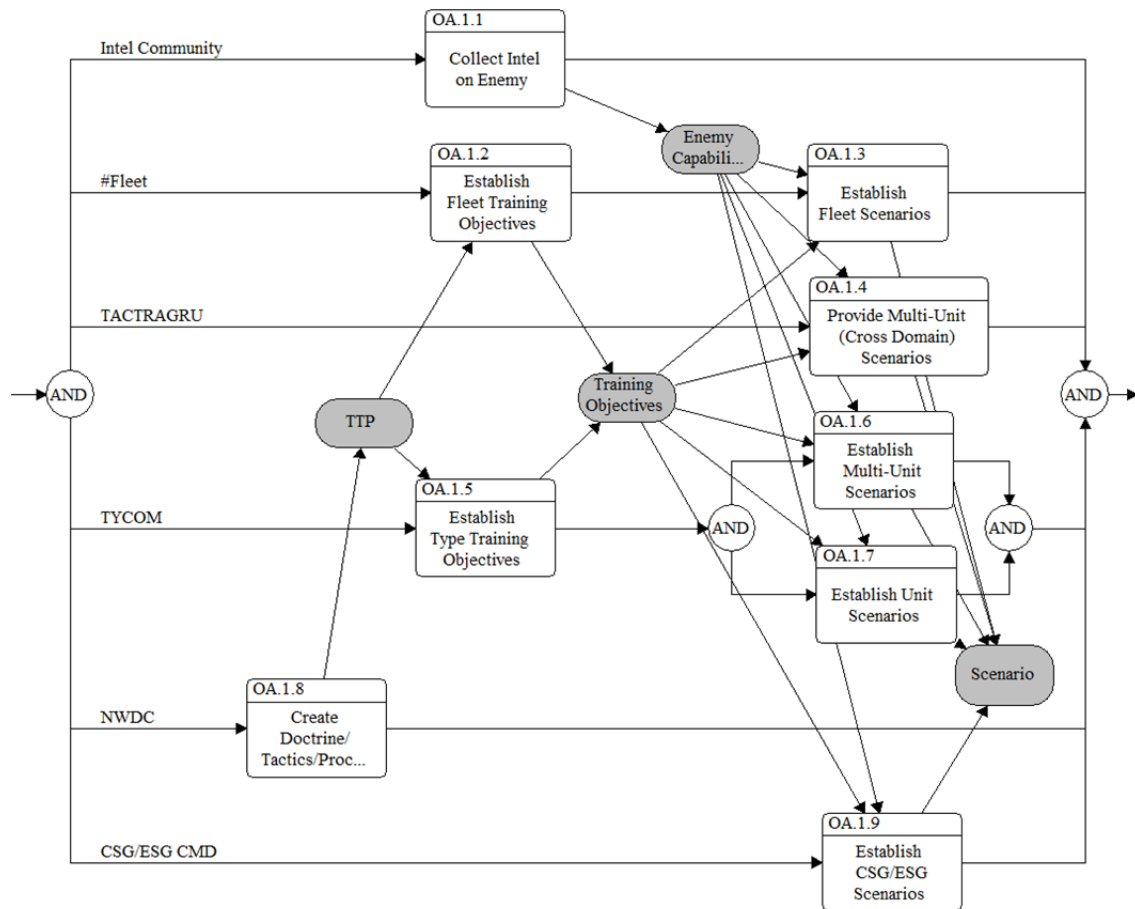


Figure 51. Support Training OV-5b

After the scenarios have been created, the WFTS transitions to the next phase. Figure 52. shows the Conduct Training operational activity. During this phase of the WFTS, units and simulators receive scenarios and intelligence that were generated and collected in the previous phase. This enables units to conduct a variety of different training (in-port, at-sea, unit, multi-unit, or any combination). As units and simulators conduct this training they are supported by the Numbered Fleet, TACTRAGRU, TYCOM, and the CSG/ESG CMDR, who can provide simulation control in order to help units meet certain training objectives required to advance through the Basic, Integrated, and Sustainment Phases of the OFRP. After a unit or simulator conducts training it will then provide feedback data that is used in the next operational activity.

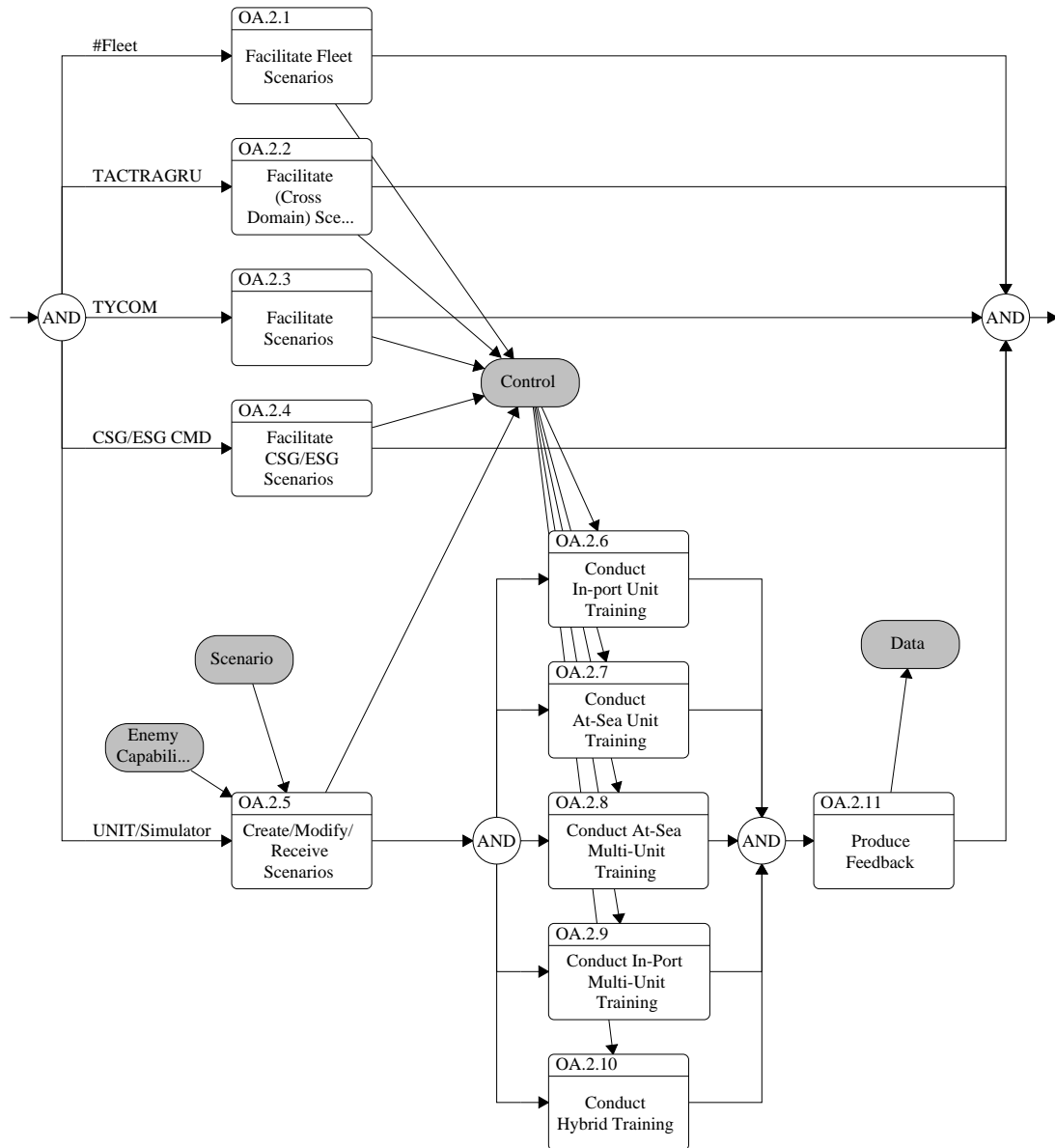


Figure 52. Conduct Training OV-5b

Figure 53 shows the feedback data supplied to the Numbered Fleet, CSG-4/15, TYCOM, or CSG/ESG CMDR for evaluation or certification purposes. Additionally, that data is passed to the NWDC so that it can be used to assess the TTPs that the Fleet is employing and how effective they are against a near-peer threat. If deemed necessary, the NWDC can then update the TTPs to allow the fleet to better react to an enemy threat.

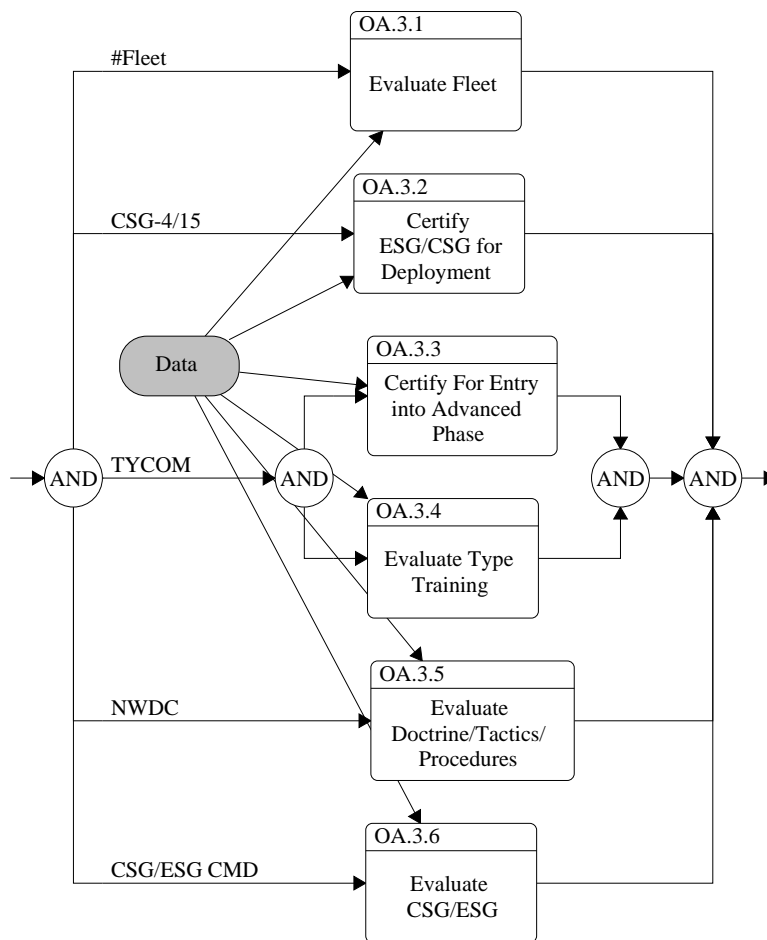
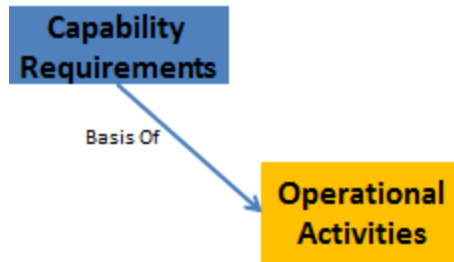


Figure 53. Evaluate Training OV-5b

5. Capability to Operation Activity Mapping (CV-6)

Figure 54 shows the relationship that the CV-6 has to the architectural overview shown in Section A of this chapter. A CV-6 maps the capability requirements that the system must have to the operational activities that are used to support those capability requirements. The Webfires training system CV-6 is located in Appendix D, Section B.



Adapted from CORE Architecture Definition Guide (DoDAF v2.02).

Figure 54. CV-6 Relationship to Overall Architecture

According to DoDAF Version 2.02:

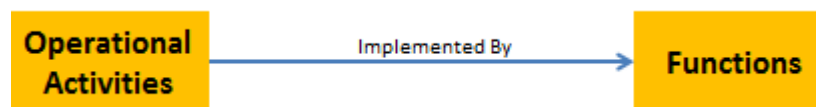
The CV-6 describes the mapping between the capabilities required and the activities that enable those capabilities.

The intended usage of the CV-6 includes:

- Tracing capability requirements to operational activities.
- Capability audit. (DOD Deputy Chief Information Officer 2017b)

6. Operational Activity to System Function Traceability Matrix (SV-5a)

Figure 55 shows the relationship that the SV-5a has to the architectural overview shown in Section A of this chapter. An SV-5a maps the Functions to the operational activities that they support. This view can be seen in Appendix D, Section C.



Adapted from CORE Architecture Definition Guide (DoDAF v2.02).

Figure 55. SV-5a Relationship to Architectural Overview

According to DoDAF Version 2.02:

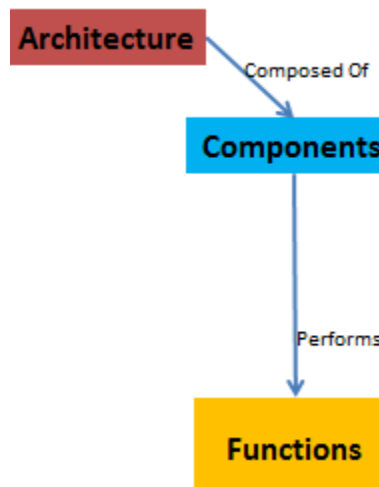
The SV-5a addresses the linkage between System Functions [...] and operational activities specified in OV-5a operational activity Decomposition Tree or OV-5b operational activity Model.

The intended usage of the SV-5a includes:

- Tracing functional system requirements to user requirements.
- Tracing solution options to requirements.
- Identification of overlaps or gaps. (DOD Deputy Chief Information Officer 2017f)

7. Function to System Traceability Matrix

Figure 56 shows the relationship that the Functions to Systems Traceability Matrix has to the architectural overview found in Section A of this chapter. A functions to systems traceability matrix maps functions to components that comprise the overall system architecture. This viewpoint is shown in Table 30.



Adapted from CORE Architecture Definition Guide (DoDAF v2.02).

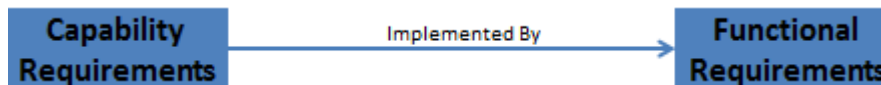
Figure 56. Functions to Systems Traceability Matrix Relationship to Overall Architecture

Table 30. WFTS Functions to Systems Traceability Matrix

| Component | Function Performs |
|--|----------------------------------|
| Artificial Intelligence Control of Simulation System | F.1 Provide Simulation |
| Centralized Data Storage System | F.5 Store Feedback Data |
| Combat Systems | F.3.1 Stimulate Sensors on Units |
| Hardwire Communication System | F.2 Communicate |
| LOS Communication System | F.2 Communicate |
| Manual Control of Simulation System | F.1 Provide Simulation |
| Mesh Network Topology | F.4 Interface With Network |
| OTH Communications System | F.2 Communicate |
| Sat LOS Communication System | F.2 Communicate |
| Simulated Combat Systems | F.3.2 Stimulate Simulators |
| Unit Control System | F.3.3 Control Simulations |

8. Capability Requirements to Functional Requirements Traceability Matrix

Figure 57 shows the relationship that the Capability Requirements to Functional Requirements Traceability Matrix has to the architectural overview found in Section A of this chapter. This figure shows that the functional requirements map back to capability requirements. The traceability matrix is shown in Appendix D, Section D.

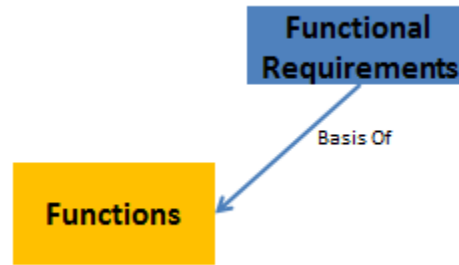


Adapted from CORE Architecture Definition Guide (DoDAF v2.02).

Figure 57. Capability Requirement to Functional Requirement Traceability Matrix Relationship to Overall Architecture

9. Functional Requirements to Functions Traceability Matrix

Figure 58 shows the relationship that the functional requirements to functions traceability matrix has to the architectural overview found in Section A of this chapter. System Functions are needed to meet Functional Requirements. The traceability matrix can be found in Appendix D, Section E.



Adapted from CORE Architecture Definition Guide (DoDAF v2.02).

Figure 58. Functional Requirements to Functions Traceability Matrix
Relationship to Overall Architecture

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XI. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A. SUMMARY

The nature of naval warfare is continuously evolving. The traditional kill chain approach is expected to be insufficient to neutralize near-peer threats in the future. To increase the combat effectiveness of the U.S. Navy in a future combat environment, the Navy is shifting its warfighting approach to a kill web, or webfires, concept of operations. In his 2016 interview with the U.S. Naval Institute, Admiral Manazir postures that unlike the current kill chain process where units are limited to engagements utilizing organic sensor data, future units will instead be able to work together to "create a cross-domain kill web" able to share combat-relevant data for the purpose of tracking and engaging an adversary (Manazir 2016). This shift in the way the Navy fights calls for a new approach to training the Navy's future warfighter. This report details a systems engineering approach for developing a webfires training system (WFTS) to prepare the future warfighter for an engagement with a near-peer threat.

Using the systems engineering process, the project team used a methodical approach to problem identification to derive a problem from the tasking statement issued by the primary stakeholder (OPNAV N9I – Director of Warfare Integration). This approach included extensive research, stakeholder identification, and stakeholder engagement, which helped refine and scope this capstone. Once the research on the current Navy training and OFRP cycle was completed, along with stakeholder research, a gap analysis was performed to determine what the current training system lacked in providing webfires training. This study identified four key capability gaps: the absence of any webfires concept training today, a lack of multi-unit training repetition to support high-velocity learning, a lack of compatible networks to support webfires training, and a lack a quality feedback to facilitate high-velocity learning.

The Navy is currently developing the webfires concept. The recent deployment of the first capable Naval Integrated Fire Control – Counter Air (NIFC-CA) strike group demonstrates that such a concept is being developed and implemented by the fleet. The

implementation of NIFC-CA is just one small aspect of the webfires concept. If all Carrier Strike Group or Expeditionary Strike Group (CSG/ESG) units are able to share fire control data with each other, then the webfires concept can be implemented across the air, surface, and undersea warfare domains (Manazir 2016). For warfighters to implement this advanced weapons system effectively, they require doctrine. This report recommends that the Naval Warfare Development Center (NWDC) coordinate with the other warfare development centers to document a unified set of tactics, techniques, and procedures (TTPs) that can be used by all warfighters to implement and train for webfires.

Additionally, the network capability of today's training system is not robust enough to support the repetition necessary to facilitate high-velocity learning and in turn results in less efficient multi-unit training. Currently, the only complete CSG/ESG multi-unit training is performed during Composite Training Unit Exercises (COMPTUEX) within the integrated phase of the Optimized Fleet Response Plan (OFRP) to certify a CSG or ESG for deployment and entry into the sustainment phase of the OFRP. Currently, the Tactical Training Groups (TTG) have the ability to facilitate fleet synthetic training (FST) events prior to COMPTUEX. However, due to the nature of the training network and the reliance on large numbers of people to conduct these FST events, the TTGs can only perform one simulation at a time. A more robust, decentralized training network along with a database of preprogrammed training simulations would greatly enhance the potential for more frequent integrated training.

Lastly, repetition is only one aspect of high-velocity learning. For high-velocity learning to be successful, training must be current, accurate, and relevant. This report recommends that the future WFTS collect and produce data that can be used by the NWDC to assess the current doctrine used to engage a near-peer threat. By incorporating a feedback loop into the training system, the doctrine can be updated to reflect better approaches to attacking an enemy during the training process, and correct deficiencies discovered in the doctrine. Additionally, the collected data could be used by the appropriate teams in certifying and evaluating units for deployment. This could potentially reduce training and certification requirements. However, for this feedback

loop to work, the NWDC, along with the certification and evaluation teams, must establish well-defined data collection and data processing requirements.

B. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations will support the U.S. Navy in implementing the WFTS:

1. Training System Architecture for Webfires Concept

The stakeholders, capability requirements, system requirements, functions, and operational activities for the WFTS were identified. Most importantly, the organizations and stakeholders determined to be a part of this WFTS were identified along with the operational activities they are assigned. These organizations and operational activities allow for the support, conduct, and evaluation of webfires training during the basic, integrated, and sustainment phases of the OFRP and support high-velocity learning.

a. Recommendations

OPNAV N9I: Provide funding and acquisition resources to support the United States Fleet Forces (USFF) Command, numbered fleets, TTGs, TYCOMs and NWDC in the following tasks.

USFF: Direct and supervise the implementation of a WFTS and direct the Number Fleets, TTGs, TYCOMS, and Warfare Development Centers with the following tasks.

Numbered Fleets: Begin to develop and implement a training strategy that includes goals and objectives to train CSG/ESGs using the Webfires Concepts for specific mission sets for their areas of responsibility. Additionally, this should be a collaborative effort along with the respective TYCOMs, TTGs, and NWDC.

TTGs: Collaborate with numbered fleets and the TYCOMs in order to help develop training goals and objectives to train CSGs and ESGs to implement a webfires concept. Additionally, work with units, numbered fleets, and TYCOMs to help create a

training scenario database that will allow units to conduct simulated training without having to coordinate with a TTG facility.

TYCOMs: Work with NWDC, TTGs, and numbered fleets to develop training goals and objectives to train CSGs and ESGs to implement webfires concepts.

NWDC: Work with all warfare development centers and the intelligence community to fully develop training, tactics, and procedures to implement webfires concepts.

2. Support Training of CSG/ESG Units during the Basic, Integrated, and Sustainment Phases of the OFRP

The envisioned training system is only a relatively small part of the total training requirements set to be accomplished during the OFRP. To be effective this system, must seamlessly integrate into future concept of operations and future training technologies should support this integration through a variety of methods.

Throughout the different phases of the OFRP we envision the need for integrated training to occur at various times of unit readiness, up to and including deployment. In order to increase the number of quality repetitions, identified as a current limitation, the need to link shore based units with deployed units must increase. The WFTS has identified technologies and organizations that support this possibility

The increase of integrated training within the future envisioned OFRP training cycle will improve training quality, retention of training and readiness. The ability to work with actual CSG/ESG units and physical contact with unit hardware will produce positive measurable results creating stronger team practices.

Along with increasing quality, the system should provide a greater in-depth feedback system. The lessons learned data from each event can be fed back to units in a shorter period of time to improve learning. The aviation training model has capitalized on an effective feedback system, giving clear results and reinforcing training principles immediately after a training event, which from research is the greatest opportunity for learning. It is envisioned that a system capitalizing on these principles could be expanded to encompass the entire CSG/ESG.

a. Recommendation

USFF, with funding provided by OPNAV N9I, should take the lead on implementing integration by directing each involved TYCOM and introducing the training system. Their efforts should focus on integrating compatible components along with standardized procedures that encourage TYCOM involvement with WFTS.

3. Leverage High-Velocity Learning through Current and Future Technology

Adversary warfighting capabilities are continuing to grow as future technology advancements come to fruition at an exponentially faster rate. To meet these continued threats, it is imperative that U.S. service men and women adapt to a new style of learning. This style is high-velocity learning, which challenges warfighters to increase the speed of the current learning cycle. In a culture of assessments and deep-rooted traditions, it is ever more important for warfighters to take charge and execute centered on the commander's intent. As technology continues to advance, the rate of data collection has increased as well. By leveraging high-velocity learning, the warfighter is better able to process and react to the new and challenging information provided.

The key to providing high-velocity learning is increasing repetition, providing effective feedback, and provide quality training. The future WFTS will provide high-velocity learning by incorporating feedback data collection, simulations, and increased connectivity.

- Clear data collection, processing, and distribution requirements must be established
- Investment into being able to provide simulations using real warfighting equipment must be made to increase the quality of training
- IA requirements, network topology, and communications bandwidth limitations must be addressed to allow more repetition and repeatability

a. Recommendation

N9I should recommend to OPNAV N2/6 they work with warfare development centers, TYCOMs and the intelligence community to develop a link that supports the

repetitive ideals of high-velocity learning. This link should reinforce learning by providing feedback at a sufficient rate, such that lessons learned can be reemployed in near real-time.

4. System Will Be Cost-Effective

Looking into the future, a quantitative cost effectiveness assessment is difficult to assemble at this time. After the 2025–2030 technology has matured, the proposed WFTS solution could be better estimated. The cost for the risk/reward and the associated technology development and implementation should change the way learning and readiness is accomplished in the fleet of tomorrow.

a. Recommendation

OPNAV-N9I engage the civilian technology sector to aid in the development of simulators and networking infrastructure capable of replacing underway combat training exercises with in-port simulations of equal or greater fidelity. It is not recommended to replace all underway combat training exercises, but replacing even a small amount of the underway training time is expected to have considerable cost savings due to the high costs associated with fuel consumption and logistics to get a unit underway. The same recommendation holds for reduced flight operations and increased high fidelity flight simulations.

It is understood that there is no substitute for training through actual system operation, but when actual system operation is so costly or logistically complex that it limits training exercises, there is some benefit to supplementing a portion of the training through actual system operations with the more cost-effective and repetitive training that simulation can bring.

C. FURTHER RESEARCH

The following items are recommended research topics that will complement the recommendations contained herein, but were judged to be outside the scope of this report

1. Cyber Domain

During the capstone project, the team focused on developing a training architecture for the webfires system. The cyber domain was considered outside the scope of the research. The successful employment of WFTS will rely on further research in the cyber domain. The team recommends two specific areas of cyber domain for further research: cyber security and information assurance. Since the WFTS is network centric, it relies heavily on external communication links to share targeting data. Future research should focus on how to defend the WFTS and its associated networks from cyber-attacks. In addition, most of the current Navy and Marine Corps training systems are stovepipe systems. These training systems are built by various contractors and have different system classifications. They do not integrate and communicate with one another. Future research should focus on information assurance to support systems integration and data protection.

2. Communication Networks

The WFTS will rely on an exceptionally high level of communications. Further research should focus on the entire electromagnetic spectrum to support communications. Having a good understanding of all the frequencies will provide a greater insight into all the available means of communication for the WFTS and identify the communication links that would optimally support WFTS. These communication links could potentially increase overall network readiness and training effectiveness.

One concept for communication speculated during the research was the concept of a Link-T. Similar to the concept of Link-16 and CEC, Link-T would be a dedicated communication network to execute the WFTS. This Link-T network would be used to transmit data for the use of simulation, simulation control data, feedback data, and other forms of data or information used to conduct training through the various phases of training.

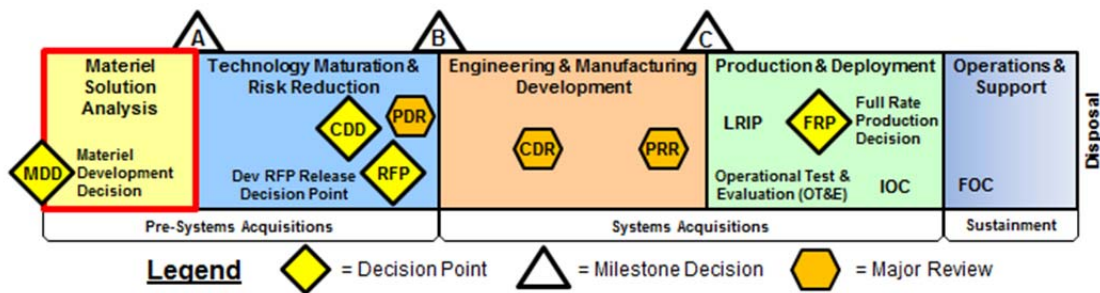
3. Artificial Intelligence and Artificial Reality

In the realm of AI and AR, this project was required to assume optimal and streamlined engagement of computer systems to contribute to robust training environments. When it comes to computing the decisions and displaying the reactions of near-peer threats based on an independent variable of blue force actions and reactions, extensive research will be required into topics such as the conceptual and computer architecture, software programming requirements, hardware capabilities, and proprietary algorithm classification.

Additionally, the extensive infrastructure requirements that are needed to augment reality on actual shipboard equipment or in a shore-based simulator facility pose a significant design problem. Further studies on the locations, costs, impacts to the OFRP for vessels that are being retrofitted/upgraded to support artificial reality, timeline for implementation, and similar information would be needed.

4. Continue Architecture/Design Including Development of an NTSP

Based on the tasking statement, the team's interpretation of that statement, and the generation of the unique problem statement, the team delivered a conceptual architecture for development of a WFTS. The process essentially paralleled a Material Solutions Analysis phase of the DOD Acquisition process and would provide a blueprint for a DOD Program Manager to enter Milestone A as seen in Figure 59.



Source: AcqNotes (2017a).

Figure 59. DOD Acquisitions Process.

The team recommends the Navy assign further research to continue through the DOD Acquisition process, beginning with production of a Naval Training Systems Plan (NTSP). This would be in accordance with OPNAV 1500.76C, which states: “Programs designated with a training KPP [key performance parameter] are required to produce a preliminary NTSP at [Milestone-A]” (Chief of Naval Operations 2013).

Finally, as technologies advance and the webfires concept comes to fruition, the team recommends further research on major parts of the Technology Maturation & Risk Reduction phase seen in Figure 59. to advance toward requirements needed for a Milestone B decision. Such topics include establishment of a Test and Evaluation Master Plan, Risk Assessment program, and technology readiness assessment (AcqNotes 2017b).

5. Acquisitions Stovepiping

To increase the cross-domain and cross-platform capabilities and trainings, further research should focus on system integration during the acquisition process. By emphasizing system integration early in the acquisition process, the SME can identify essential system integration requirements for the developing systems. Understanding these system integration requirements would significantly increase interoperability between the developing systems and the established systems. This will result in increased integration and readiness of the webfires system and the training system.

6. Face-to-Face Briefing/Debriefing

To help increase webfires training effectiveness, further research needs to focus on face-to-face briefing and other means of briefing. The face-to-face debriefing process involves all the training participants meeting together immediately after the training event for a final debrief. Being able to meet face to face to review the previous training event can potentially increase teamwork, quality of feedback, and training fidelity. While face-to-face debriefing is valuable, it is not always practical out at sea. Further research should focus on other means of briefing, such as video teleconference and virtual communications.

7. Helping of Certification and Evaluation

The team developed a WFTS that provides training data for evaluation and certification. Further research needs to focus on determining what data is required by various stakeholders and how to utilize these training data. Being able to utilize these training data effectively can potentially increase training effectiveness, reduce evaluation and certification time, and update a unit's readiness.

8. Warfare Subject Matter Experts

Based on stakeholder feedback, the team found implementing SMEs has long been recognized in the aviation community as a best practice. The aviation community retained superior tactical talent for considerable time within an operational environment, allowing for quality training that was better retained by the warfighters. The surface warfare community has begun to implement procedures that have been modeled after these best practices with positive results. As the Navy's mission begins implementing more cross-domain operations, further research will be needed to understand how all communities and platforms can produce a cadre of SMEs, and how to best employ their time and talent into maximizing benefits from their tactical efficiencies.

APPENDIX A. OFFICIAL TASKING STATEMENT



2 Aug 16

Memorandum for Systems Engineering Analysis Cohort 25 (SEA25)

Subj: FY2017 SEA25 Capstone Projects: Tasking and Timelines

Enclosures:

Tab A: Developing warfighting training to leverage the web fires concept and technology

Tab B: NPS Warfare Innovation Continuum "Strengthen naval power at and from the sea"

Tab C: IRB Student Checklist

1. This memorandum provides the FY2017 guidance for the conduct of the Systems Engineering Analysis (SEA) integrated project, which is required as partial fulfillment for the SEA degree. SEA students will deliver completed project reports and final briefing materials to faculty advisors in accordance with the following plan and milestones. Each group will:
 - a. Develop project proposals and management plans during the Fall Quarter AY2017. These proposals and plans will serve to focus initial research and analysis. These plans will be reviewed and updated frequently as research progresses.
 - b. Conduct project reviews approximately every six weeks, finishing with a final brief to interested stakeholders on and off campus.
 - c. Assign a report lead from each team. Work closely with faculty advisors to prepare the final reports for faculty advisor signature by four work-weeks before graduation. The final reports are then due to the SEA chairman one week later; and to the Operations Research and Systems Engineering department chairmen one week before graduation.
2. SEA students are expected to identify and integrate students and faculty from across the campus – and also from outside NPS – to participate directly in the project or to provide source documents, technical knowledge and insights, and knowledge of evolving requirements, capabilities, and systems. This participation could include students who would join project groups; students doing related individual thesis topics from TSSE, TDSI, OR, IS or SE; faculty inside or outside NPS who have expertise related to the project; and appropriately engaged government agencies and industry developers. It is the students' responsibility to integrate the efforts of outside participants in the projects. Faculty advisors and the SEA Chair will, of course, significantly assist in these efforts.
3. Prior to commencing the formalized systems engineering and analysis process including stakeholder analysis, the SEA team will consult with Dr. Larry Shattuck, Chairman of the NPS Institutional Review Board and submit to him TAB A, a general description of the team's systems and analytical approach to address the tasking, a completed IRB student research form (Tab C) and a list of candidate questions for stakeholders to review. The intent is to ensure questions are oriented about the "what" of the systems and not about the "who" of the stakeholder.

4. The analysis will employ the systems engineering and operations research methodologies presented in class work and from the project advisors. The role of the SEA students is that of the lead project systems engineering team, working closely with other members of the project engineering teams from TDSI and other campus curricula. SEA students will be expected to define the functions and performance of systems, develop alternative architectures to meet those functions, and evaluate the alternative architectures for performance and cost. In executing these tasks, students will be defining and understanding the overall project requirements, recognizing that the definition process is iterative and will evolve as the project progresses.
5. Grades are assigned to the participants in these projects. Although work is performed as part of a team, individual performance will be the basis for this evaluation. Successful completion and documentation of the project is a degree requirement.
6. The SEA25 project will build on, possibly challenge, but not replicate, other DOD and SEA projects. SEA25 will examine virtual environment technologies for potential contributions to establish effective training in web fires tactics and employment. SEA25 will coordinate their study efforts, participate and occupy leadership roles in other FY16/17 efforts at NPS aimed at strengthening naval power at and from the sea. These activities, coordinated by the Chair of Systems Engineering Analysis are described in Tab B.



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Distribution: SEA25 students; Profs. Hughes, Jacobs, Giachetti, Hatch, Whitcomb, Stevens, Solitario, Kline, Harney, Papoulias, Porter, Boger, Brutzman, Buettner, McDowell, President Route; Provost Hensler; Deans Wirtz, Scandrett, McCormick, Paduan, and Moses, CAPT Daniel Verheul; Dr. Shattuck; LCDR Naccarato, RDML Williams, RADM Ellis, Mr. Paul Lluv (OPNAV N9B), RADM Fanta (OPNAV N9I), Mr. Steve Dreiss (OPNAV N9IB), Mr. Mike Novak (OPNAV N99B), Mr. Chuck Werchado (N81B), and Ms. Kathie Cain

TAB A

SEA 25 Tasking

Developing warfighting training to leverage web fires concepts and technologies.

Design a fleet system of systems and concept of operations for employment of a cost effective training system capable of preparing naval warfighters to employ and leverage the web fires concepts and technologies in the 2025-2030 timeframe. Consider training across warfare specialties and missions. Conduct research to provide a solid foundation of knowledge requirements for a web fires fleet concept. Then complete a gap analysis by comparing current fleet training with the required training to leverage cross domain and cross-platform capabilities in a warfighting environment. Scan for current examples of cross-domain training and current training simulation from DoD and industry. Develop a system architecture addressing responsible command, training requirements, training and exercise venues, and training participants to fill discovered gaps in meeting the knowledge requirements. Assess the proposed system against the principles of high velocity learning found in the CNO's "A Design for Maintaining Maritime Superiority"

Advisors:

Senior Lecturer Bill Hatch, Graduate School of Business and Public Policy
TBD, Systems Engineering Department
Dr. Michael Atkinson, Operations Research Department

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APPENDIX B. OFRP OPERATIONAL ACTIVITY SUMMARY TABLE

| OA# | Operational Activity | Performer | Input | Output |
|--------|---|-------------------|--|--|
| OA.1.1 | Manage Sustainment Training | # Fleet Commander | Sustainment Training Feedback Unit Sustainment Training Status | Sustainment Training Requirements |
| OA.2.1 | Manage Integrated Training | # Fleet Commander | Unit Integrated Training Status | Integrated Training/ Certification Requirements |
| OA.1.2 | Monitor Unit Status (Sustainment) | CSG/ESG Commander | Sustainment Training Feedback Sustainment Training Requirements Unit Sustainment Training Status | |
| OA.1.3 | Direct Units (Sustainment) | CSG/ESG Commander | | Unit Direction (Sustainment) |
| OA.1.4 | Receive Training Requirements (Sustainment) | CSG/ESG Unit | Sustainment Training Requirements | |
| OA.1.5 | Conduct Sustainment Training | CSG/ESG Unit | Unit Direction (Sustainment) | |
| OA.1.6 | Document Sustainment Training | CSG/ESG Unit | | Unit Sustainment Training Status |
| OA.1.7 | Provide Sustainment Training Feedback | CSG/ESG Unit | | Sustainment Training Feedback |
| OA.2.2 | Facilitate Integrated Training | TACTRAGROUP | Integrated Training/ Certification Requirements | Integrated Training |
| OA.3.1 | Manage Unit Level Training | TYCOM | Unit Level Training Feedback Unit Level Training Status | Unit Level Training/ Certification Requirements |

| OA# | Operational Activity | Performer | Input | Output |
|------------|--|------------------------|---|---|
| OA.3.2 | Manage WDCs | TYCOM | Unit Level Training Feedback | Doctrine Guidance Procedure Guidance |
| OA.2.8 | Receive Evaluation Requirements (Integrated) | Certification Programs | Integrated Training/ Certification Requirements | |
| OA.2.9 | Evaluate Units (Integrated) | Certification Programs | Integrated Unit Performance | Unit Integrated Training Status |
| OA.3.3 | Receive Unit Level Evaluation Requirements | Certification Programs | Unit Level Training/ Certification Requirements | |
| OA.3.4 | Evaluate Unit Level Performance | Certification Programs | Unit Level Performance | Unit Level Training Status |
| OA.2.3 | Monitor Unit Status (Integrated) | CSG/ESG Commander | Integrated Training Feedback Integrated Training/ Certification Requirements Integrated Unit Performance Unit Integrated Training Status | |
| OA.2.4 | Direct Units (Integrated) | CSG/ESG Commander | | Unit Direction (Integrated) |
| OA.2.10 | Receive Training Requirements (Integrated) | CSG/ESG Unit | Integrated Training/ Certification Requirements | |
| OA.2.11 | Conduct Integrated Training | CSG/ESG Unit | Integrated Training Unit Direction (Integrated) | |
| OA.2.12 | Document Training (Integrated) | CSG/ESG Unit | | Integrated Unit Performance |
| OA.2.13 | Provide Integrated Training Feedback | CSG/ESG Unit | | Integrated Training Feedback |

| OA# | Operational Activity | Performer | Input | Output |
|------------|--|-------------------------------|---|---|
| OA.3.8 | Receive Training Requirements (Unit Level) | CSG/ESG Unit | Doctrine Guidance Procedure Guidance Unit Level Training/ Certification Requirements | |
| OA.3.9 | Conduct Unit Training | CSG/ESG Unit | Unit Level Training (Through Facilities) | |
| OA.3.10 | Document Unit Level Training | CSG/ESG Unit | | Unit Level Performance |
| OA.3.11 | Provide Unit Level Training Feedback | CSG/ESG Unit | | Unit Level Training Feedback |
| OA.2.5 | Receive Integrated Training Requirements | Fleet Level Training Facility | Integrated Training/ Certification Requirements | |
| OA.2.6 | Provide Interactive Training (Integrated) | Fleet Level Training Facility | | Integrated Training |
| OA.2.7 | Evaluate Interactive Training (Integrated) | Fleet Level Training Facility | Integrated Unit Performance | Integrated Training Feedback Unit Integrated Training Status |
| OA.3.5 | Receive Unit Level Training Requirements | Fleet Level Training Facility | Unit Level Training/ Certification Requirements | |
| OA.3.6 | Provide Interactive Unit Level Training | Fleet Level Training Facility | | Unit Level Training (Through Facilities) |
| OA.3.7 | Evaluate Unit Level Interactive Training | Fleet Level Training Facility | Unit Level Performance | Unit Level Training Status |

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APPENDIX C. COMPONENT TRADE-OFF ANALYSIS SUMMARY

| | Category | Advantages | Disadvantages |
|---------------------|-------------------------|---|--|
| Provide Simulations | Artificial Intelligence | <ul style="list-style-type: none"> - Potential to Mimic Tactical Fidelity of Manual Control - Not Relying on SME to Run Scenarios | <ul style="list-style-type: none"> - Expensive to Program and Develop - Time Intensive to Develop |
| | Manual | <ul style="list-style-type: none"> - Realistic Tactics - Highest Fidelity Tactics (Real Time Responses and Delays) | <ul style="list-style-type: none"> - High SME Demand - Labor Intensive - Time Consuming |
| | Preprogrammed | <ul style="list-style-type: none"> - Low Cost - High Repetition - Range Greatly in Complexity - Easily Tailored to Meet Training Objectives | <ul style="list-style-type: none"> - Lowest Fidelity - Potentially “Game” the Scenario after a Few Repetitions |
| Communicate | Hard Wire (LAN Line) | <ul style="list-style-type: none"> - High Data Rate - Cheap and Simple over Short Distances | <ul style="list-style-type: none"> - Does Not Have At-Sea Capability - Expensive over Long Distances |
| | Over The Horizon (OTH) | <ul style="list-style-type: none"> - Greater Ranges than LOS Communications | <ul style="list-style-type: none"> - Lowest Data Rate - HF possible RADHAZ |
| | Line Of Sight (LOS) | <ul style="list-style-type: none"> - Low cost - Not Relying on SATCOMS - Moderate to high data rates | <ul style="list-style-type: none"> - No Over the Horizon Capability - Point to Point LOS between Ships in Port Might be A RADHAZ |
| | Satellite Coms | <ul style="list-style-type: none"> - Cover Great Ranges - Moderate Data Rates | <ul style="list-style-type: none"> - High Cost |
| Stimulate Units | Non-Console | <ul style="list-style-type: none"> - Low Cost - Great for Individual Training | <ul style="list-style-type: none"> - Lowest Fidelity |
| | Simulated Console | <ul style="list-style-type: none"> - Great for Unit Training - Available to Multiple Units | <ul style="list-style-type: none"> - Medium to Low Fidelity - Does Not Train to Equipment Operation |
| | Actual Console | <ul style="list-style-type: none"> - Highest Fidelity | <ul style="list-style-type: none"> - Expensive Simulators/ Facilities |
| Control | Central Control | <ul style="list-style-type: none"> - Unity of Command - SME Only Needed at Central Location | <ul style="list-style-type: none"> - Single Point of Failure - Potentially Limited Repetition |

| | | | |
|------------------------|--------------------------------|---|--|
| | Local Control | <ul style="list-style-type: none"> - Not Required Central Control - Unity of Command - Potentially Increased Repetition | - Single Point of Failure |
| | Unit Control | <ul style="list-style-type: none"> - All Webfires Capable Units Can Control Simulation - Increases Repetition - Not Relying on Central or Local node | - Difficult to Manage Large Training Events |
| Interface with Network | Star Network (Shore-Side) | <ul style="list-style-type: none"> - Central Hub Controls and Monitors All Units - Easy to Connect and Disconnect from Central Hub | <ul style="list-style-type: none"> - Single Point of Failure - All Non-Central Units Must Connect to a Central Hub |
| | Multiple-Stars (Shore and Sea) | <ul style="list-style-type: none"> - Enable More Units to Joint Training - Easy to Connect and Disconnect from Central Hub | <ul style="list-style-type: none"> - Single Point of Failure - All Non-Central Units Must Connect to a Central Hub |
| | Mesh Network | <ul style="list-style-type: none"> - Very Reliable | <ul style="list-style-type: none"> - Expensive - Very Complicated |
| Store Data | Centralized | <ul style="list-style-type: none"> - Whole Picture Data - Highly Accessible | - Single Point of Failure |
| | Local | <ul style="list-style-type: none"> - Units Can Recall Own Data Independent of Networks | <ul style="list-style-type: none"> - Must Have Storage Capability at Each Unit - Partial Picture Data |
| | Portable Media | <ul style="list-style-type: none"> - Low Cost - Convenient | <ul style="list-style-type: none"> - Must Have Storage Capability at Each Unit - Time Delay to Transfer Media from Portable Storage to Destination - Partial Picture Data |

APPENDIX D. WEBFIRES TRAINING SYSTEM ARCHITECTURE

A. OPERATIONAL ITEMS TRANSFER MATRIX

| Nodes Connected To | Operational Items Transferred | Description |
|--------------------------------|-------------------------------|---|
| #Fleet Unit/Simulator | Control & Data & Scenario | Data (Feedback Data) will be passed from Units and Simulators for the purpose of evaluation or certifications. |
| TYCOM Unit/Simulator | Control & Data & Scenario | |
| TACTRAGRU Unit/Simulator | Control & Data & Scenario | |
| CSG/ESG CMDR Unit/Simulator | Control & Data & Scenario | |
| Intel Community TACTRAGRU | Enemy Capabilities/Tactics | The Intelligence Community will update and pass the enemies capabilities and tactics to the organizations that are involved in running the Units/Simulators as well as the Units/Simulators themselves. |
| #Fleet Intel Community | Enemy Capabilities/Tactics | |
| Intel Community Unit/Simulator | Enemy Capabilities/Tactics | |
| Intel Community TYCOM | Enemy Capabilities/Tactics | |
| CSG/ESG CMDR Intel Community | Enemy Capabilities/Tactics | |
| CSG-4/15 Unit/Simulator | Data | Data (Feedback Data) will be passed to NWDC for use to update TTPs. Additionally, data will be used for evaluation or certification by the CSG-4/15 responsible for certifying a Strike Group for deployment. |
| NWDC Unit/Simulator | Data | |
| #Fleet TYCOM | Training Objectives | The #Fleets and the TYCOMs will pass training objectives to the organizations that are responsible for establishing training scenarios and training Units and Strike Groups. |
| #Fleet CSG/ESG CMDR | Training Objectives | |
| TACTRAGRU TYCOM | Training Objectives | |
| CSG/ESG CMDR TYCOM | Training Objectives | |
| #Fleet | Training Objectives | |

| Nodes Connected To | Operational Items Transferred | Description |
|-------------------------------|--|---|
| TACTRAGRU | | |
| #Fleet NWDC | TTP | NWDC will provide Webfires TTPs that can be used to establish Training Objectives for Units and Strike Groups. |
| NWDC TYCOM | TTP | |

B. WEBFIRES TRAINING SYSTEM CV-6 TABLE

| Cap Req# | Capability Requirements | Operational Activities |
|------------|--|--|
| CapReq.1 | Repetition | |
| CapReq.1.1 | Provide Training Scenarios | OA.1.1 Collect Intel on Enemy OA.1.4 Provide Multi-Unit (Cross Domain) Scenarios OA.1.6 Establish Multi-Unit Scenarios OA.1.7 Establish Unit Scenarios |
| CapReq.1.2 | Run simulations independently between units and simulators | OA.2.1 Facilitate Fleet Scenarios OA.2.2 Facilitate (Cross Domain) Scenarios OA.2.3 Facilitate Scenarios OA.2.4 Facilitate CSG/ESG Scenarios OA.2.5 Create/Modify/Receive Scenarios OA.2.6 Conduct In-port Unit Training OA.2.7 Conduct At-Sea Unit Training OA.2.8 Conduct At-Sea Multi-Unit Training OA.2.9 Conduct In-Port Multi-Unit Training OA.2.10 Conduct Hybrid Training |
| CapReq.1.3 | Train with limited communications | OA.2.1 Facilitate Fleet Scenarios OA.2.2 Facilitate (Cross Domain) Scenarios OA.2.3 Facilitate Scenarios OA.2.4 Facilitate CSG/ESG Scenarios OA.2.5 Create/Modify/Receive Scenarios OA.2.6 Conduct In-port Unit Training OA.2.7 Conduct At-Sea Unit Training OA.2.8 Conduct At-Sea Multi-Unit Training OA.2.9 Conduct In-Port Multi-Unit Training OA.2.10 Conduct Hybrid Training |
| CapReq.2 | Feedback | |
| CapReq.2.1 | Provide Data for certification and evaluation | OA.2.11 Produce Feedback OA.3.1 Evaluate Fleet OA.3.2 Certify ESG/CSG for Deployment OA.3.3 Certify For Entry into Advanced Phase OA.3.4 Evaluate Type Training OA.3.6 Evaluate CSG/ESG |
| CapReq.2.2 | Provide Data to update TTP | OA.2.11 Produce Feedback OA.3.5 Evaluate Doctrine/Tactics/Procedures |
| CapReq.3 | Integration | OA.2.6 Conduct In-port Unit Training OA.2.7 Conduct At-Sea Unit Training OA.2.8 Conduct At-Sea Multi-Unit Training OA.2.9 Conduct In-Port Multi-Unit Training OA.2.10 Conduct Hybrid Training |
| CapReq.4 | Webfires Concept Training | |

| Cap Req# | Capability Requirements | Operational Activities |
|------------|------------------------------|---|
| CapReq.4.1 | In-port and At-sea | OA.1.8 Create Doctrine/Tactics/Procedures OA.2.6 Conduct In-port Unit Training OA.2.7 Conduct At-Sea Unit Training OA.2.8 Conduct At-Sea Multi-Unit Training OA.2.9 Conduct In-Port Multi-Unit Training OA.2.10 Conduct Hybrid Training |
| CapReq.4.2 | Multi-Unit and Unit Training | OA.1.8 Create Doctrine/Tactics/Procedures OA.2.8 Conduct At-Sea Multi-Unit Training OA.2.9 Conduct In-Port Multi-Unit Training OA.2.10 Conduct Hybrid Training |
| CapReq.4.3 | OFRP | OA.1.2 Establish Fleet Training Objectives OA.1.3 Establish Fleet Scenarios OA.1.4 Provide Multi-Unit (Cross Domain) Scenarios OA.1.5 Establish Type Training Objectives OA.1.6 Establish Multi-Unit Scenarios OA.1.7 Establish Unit Scenarios OA.1.8 Create Doctrine/Tactics/Procedures OA.1.9 Establish CSG/ESG Scenarios OA.2.1 Facilitate Fleet Scenarios OA.2.2 Facilitate (Cross Domain) Scenarios OA.2.3 Facilitate Scenarios OA.2.4 Facilitate CSG/ESG Scenarios OA.2.5 Create/Modify/Receive Scenarios |

C. WEBFIRES TRAINING SYSTEM SV-5A TABLE

| OA # | Operational Activity | Implemented By |
|-------------|---|--|
| OA.1 | Support Training | |
| OA.1.1 | Collect Intel on Enemy | No Function to support this operational activity |
| OA.1.2 | Establish Fleet Training Objectives | No Function to support this operational activity |
| OA.1.3 | Establish Fleet Scenarios | F.1.1 Create Simulation F.1.2 Store Simulation F.1.3 Modify Existing Simulation F.1.4 Receive Intel Updates |
| OA.1.4 | Provide Multi-Unit (Cross Domain) Scenarios | F.1.1 Create Simulation F.1.2 Store Simulation F.1.3 Modify Existing Simulation F.1.4 Receive Intel Updates |
| OA.1.5 | Establish Type Training Objectives | No Function to support this operational activity |
| OA.1.6 | Establish Multi-Unit Scenarios | F.1.1 Create Simulation F.1.2 Store Simulation F.1.3 Modify Existing Simulation F.1.4 Receive Intel Updates |
| OA.1.7 | Establish Unit Scenarios | F.1.1 Create Simulation F.1.2 Store Simulation F.1.3 Modify Existing Simulation F.1.4 Receive Intel Updates |
| OA.1.8 | Create Doctrine/Tactics/ Procedures | No Function to support this operational activity |
| OA.1.9 | Establish CSG/ESG Scenarios | F.1.1 Create Simulation F.1.2 Store Simulation F.1.3 Modify Existing Simulation F.1.4 Receive Intel Updates |
| OA.2 | Conduct Training | |
| OA.2.1 | Facilitate Fleet Scenarios | F.1.5 Receive Simulations F.3.3 Control Simulations F.4.1 Interface with Human F.4.2 Interface With System |
| OA.2.2 | Facilitate (Cross Domain) Scenarios | F.1.5 Receive Simulations F.3.3 Control Simulations F.4.1 Interface with Human F.4.2 Interface With System |

| OA # | Operational Activity | Implemented By |
|-------------|-------------------------------------|--|
| OA.2.3 | Facilitate Scenarios | F.1.5 Receive Simulations F.3.3 Control Simulations F.4.1 Interface with Human F.4.2 Interface With System |
| OA.2.4 | Facilitate CSG/ESG Scenarios | F.1.5 Receive Simulations F.3.3 Control Simulations F.4.1 Interface with Human F.4.2 Interface With System |
| OA.2.5 | Create/Modify/Receive Scenarios | F.1.1 Create Simulation F.1.2 Store Simulation F.1.3 Modify Existing Simulation F.1.4 Receive Intel Updates F.1.5 Receive Simulations F.2.3 Transmit Simulations |
| OA.2.6 | Conduct In-port Unit Training | F.2.2 Transmit Voice F.3.1 Stimulate Sensors on Units F.3.2 Stimulate Simulators F.3.3 Control Simulations F.4.1 Interface with Human F.4.2 Interface With System |
| OA.2.7 | Conduct At-Sea Unit Training | F.2.2 Transmit Voice F.3.1 Stimulate Sensors on Units F.3.2 Stimulate Simulators F.3.3 Control Simulations F.4.1 Interface with Human F.4.2 Interface With System |
| OA.2.8 | Conduct At-Sea Multi-Unit Training | F.2.2 Transmit Voice F.3.1 Stimulate Sensors on Units F.3.2 Stimulate Simulators F.3.3 Control Simulations F.4.1 Interface with Human F.4.2 Interface With System |
| OA.2.9 | Conduct In-Port Multi-Unit Training | F.2.2 Transmit Voice F.3.1 Stimulate Sensors on Units F.3.2 Stimulate Simulators F.3.3 Control Simulations F.4.1 Interface with Human F.4.2 Interface With System |

| OA # | Operational Activity | Implemented By |
|-------------|---------------------------------------|--|
| OA.2.10 | Conduct Hybrid Training | F.2.2 Transmit Voice F.3.1 Stimulate Sensors on Units F.3.2 Stimulate Simulators F.3.3 Control Simulations F.4.1 Interface with Human F.4.2 Interface With System |
| OA.2.11 | Produce Feedback | F.5.1 Store Performance Data F.5.2 Store Event Data |
| OA.3 | Evaluate Training | |
| OA.3.1 | Evaluate Fleet | F.2.1 Transmit Feedback Data |
| OA.3.2 | Certify ESG/CSG for Deployment | F.2.1 Transmit Feedback Data |
| OA.3.3 | Certify For Entry into Advanced Phase | F.2.1 Transmit Feedback Data |
| OA.3.4 | Evaluate Type Training | F.2.1 Transmit Feedback Data |
| OA.3.5 | Evaluate Doctrine/Tactics/Procedures | F.2.1 Transmit Feedback Data |
| OA.3.6 | Evaluate CSG/ESG | F.2.1 Transmit Feedback Data |

**D. CAPABILITY REQUIREMENTS TO FUNCTIONAL REQUIREMENTS
TRACEABILITY MATRIX**

| CapReq# | Capability Requirements | Functional Requirement |
|----------------|--|---|
| CapReq.1 | Repetition | |
| CapReq.1.1 | Provide Training Scenarios | Req 3 Receive Intel Updates Req 5 Preprogrammed Simulations Req 6 Modify Simulations Req 7 Create Simulations Req 11 Provide Simulation Storage |
| CapReq.1.2 | Run simulations independently between units and simulators | Req 8 Simultaneous Simulations Req 9 Support Multiple Simulations Req 10 Simulation Control |
| CapReq.1.3 | Train with limited communications | Req 14 Communication |
| CapReq.2 | Feedback | |
| CapReq.2.1 | Provide Data for certification and evaluation | Req 12 Collect and Provide Data Req 13 Aid Cert and Eval |
| CapReq.2.2 | Provide Data to update TTP | Req 12 Collect and Provide Data |
| CapReq.3 | Integration | Req 1 Integrate CSG/ESG Units' Weapon Systems Req 2 Interface with Training Facilities and Simulators Req 4 Compatibility |
| CapReq.4 | Webfires Concept Training | |
| CapReq.4.1 | In-port and At-sea | Req 1 Integrate CSG/ESG Units' Weapon Systems Req 2 Interface with Training Facilities and Simulators Req 4 Compatibility |
| CapReq.4.2 | Multi-Unit and Unit Training | Req 1 Integrate CSG/ESG Units' Weapon Systems Req 2 Interface with Training Facilities and Simulators Req 4 Compatibility |

| CapReq# | Capability Requirements | Functional Requirement |
|----------------|--------------------------------|--|
| CapReq.4.3 | OFRP | Req 1 Integrate CSG/ESG Units' Weapon Systems Req 2 Interface with Training Facilities and Simulators Req 4 Compatibility Req 12 Collect and Provide Data Req 13 Aid Cert and Eval |

E. FUNCTIONAL REQUIREMENTS TO FUNCTIONS TRACEABILITY MATRIX

| Req # | Requirement | Basis Of |
|--------------|---|---|
| 1 | Integrate CSG/ESG Units' Weapon Systems | F.3.1 Stimulate Sensors on Units F.4.2 Interface With System F.4.2.1 Provide Multi-Unit Network F.4.2.1.1 Connect Units F.4.2.1.1.1 Connect Units In-port F.4.2.1.1.2 Connect Units At-sea F.4.2.2 Provide Standalone Network |
| 2 | Interface with Training Facilities and Simulators | F.4.2 Interface With System F.4.2.1 Provide Multi-Unit Network F.4.2.1.2 Connect Simulators F.4.2.2 Provide Standalone Network |
| 3 | Receive Intel Updates | F.1.4 Receive Intel Updates |
| 4 | Compatibility | F.1.4 Receive Intel Updates |
| 5 | Pre-Programmed Simulations | F.1.1 Create Simulation F.1.2 Store Simulation F.1.5 Receive Simulations |
| 6 | Modify Simulations | F.1.3 Modify Existing Simulation |
| 7 | Create Simulations | F.1.1 Create Simulation |
| 8 | Simultaneous Simulations | F.3.1 Stimulate Sensors on Units F.3.2 Stimulate Simulators F.3.3 Control Simulations F.4.1 Interface with Human F.4.1.1 Provide Control Display F.4.1.2 Provide HMI |
| 9 | Support Multiple Simulations | F.3.1 Stimulate Sensors on Units F.3.2 Stimulate Simulators F.3.3 Control Simulations F.4.1 Interface with Human F.4.1.1 Provide Control Display F.4.1.2 Provide HMI F.4.2.1 Provide Multi-Unit Network F.4.2.2 Provide Standalone Network |
| 10 | Simulation Control | F.3.3 Control Simulations F.4.1 Interface with Human F.4.1.1 Provide Control Display F.4.1.2 Provide HMI |
| 11 | Provide Simulation Storage | F.1.2 Store Simulation |
| 12 | Collect and Provide Data | F.5.1 Store Performance Data |

| Req # | Requirement | Basis Of |
|--------------|--------------------|--|
| | | F.5.2 Store Event Data |
| 13 | Aid Cert and Eval | F.5.1 Store Performance Data F.5.2 Store Event Data |
| 14 | Communication | F.2.1 Transmit Feedback Data F.2.2 Transmit Voice F.2.3 Transmit Simulations |

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APPENDIX E. IRB DOCUMENTATION

A. ORIGINAL SEA-25 CAPSTONE PROJECT QUESTIONS

Mission (Tasks):

1. Define the scale of “web-fires” in the realm of Air/Surface/Undersea/Cyber.
 - a. What types of training will be required?
2. Are there specific Mission Essential Task Lists (METL) items for this project for cross-domain training?
 - a. What are the prioritization levels of these METLs?
 - b. Who are the primary stakeholders that would define the most significant METLs?
 - c. Are there METLs that we should seek to focus on for creating training and developing tactics?
3. What is the expectation of effective tactical training?

Cross-Domain Training:

1. What are the existing technologies used for cross-domain training?
2. What are some challenges to incorporate cross-domain communications with webfires?
3. What training systems are currently available for incorporation of webfires?
4. What current capabilities do systems provide in integrated training?
How does [insert company/organization name] approach cross-domain training?
 - a. Addressing the challenges/constraints listed above, how does the respective [company/organization name] incorporate and adapt to these challenges?
 - b. What technology is capable of operating in a webfires environment?
 - c. Is this platform specific training or universal?
5. What challenges have [insert company/organization name] encountered in cross-domain training?
 - a. Particularly from the perspective of joint interoperability
 - b. Particularly from the perspective of operating in an integrated communications environment
6. What requirements would [insert company/organization name] place on a system operating in the cross-domain training environment?
 - a. Do these requirements align with the requirements that we have been given for this project?
 - b. Should additional requirements be added to help scope-down our project?
 - c. How are these requirements prioritized?
 - i. What are the Key Performance Parameter (KPP) requirements (aka the “non- negotiables”)?
7. What current Navy/Joint systems support integrated webfires training?

- a. Cooperative Engagement Capability (CEC)?
- b. Link 11/16?
- c. Battleforce Tactical Trainer (BFTT)

Infrastructure Security:

1. What controls are made to prevent an adversary from gaining access or disturbing these training systems?
 - a. Compromising training by hacking into / stealing / destroying, etc.
2. What are the challenges in communication with a network of webfires especially underwater units? How is bandwidth to be controlled if there are multiple units or nodes in use at one time in the same network?
3. How will these training platforms maintain comms with other platforms in EMCON status?
 - a. What are the challenges?
 - b. What is the way-around?
4. What will webfires be capable of be in 10 years?
 - a. All domains (Air/Surface/Sub-surface)
5. What capabilities will the training system have in terms of communicating with other platforms?
6. What other training systems are currently being fielded?
 - a. EM environment (jamming)?
 - b. Long-range communications extension?
 - c. Weapons delivery?
 - d. Stand-Alone?
7. What is the envisaged extent of this system for U.S. military training?
 - a. Does it replace manned systems or complement them?
8. What are the challenges experienced by users when dealing with cyber training?

Technology:

1. What sensors are currently available for incorporation into the training? Are these sensors capable of operating in a denied environment? How would the information that these sensors obtain be relayed to the training system?
 - a. Once information is gathered by a sensor, what is the network path for delivery?
2. Are we seeking to strictly use existing capabilities and repurposing AND/OR develop an entirely new system?
 - a. Is there a system currently being fielded that supports interoperability training in a denied environment? Can we use that training system as a template/model for our future defined training system? (For example: Does our prospective training system mimic other systems such as NIFC-CA or other Integrated Fire Control (IFC) related systems or BFTT?)

3. Will the U.S. Navy have technology that will be capable of passing large amounts of data through the water that will have the speed of kbps, or mbps, not the current bps?
4. What are the considerations to develop the next generation of C4ISR network centric architecture to support cross-domain training?

NPS IRB
HSR Determination Checklist
last updated: 12/31/12

Instructions: This form is to be completed by the IRB Chair or Vice-Chair when providing an official IRB determination on whether a proposed activity meets the federal definition of research with human subjects according to 32 CFR 219. After completing the form provide to the IRB Administrator. The IRB Administrator will notify the investigators and file electronically.

| | | | |
|-----------------|--|-------------|-----------------------------|
| Research Title: | Developing warfighting training to leverage web fires concepts and technologies | | |
| PI: | Prof. Fotis Papoulias | Department: | System Engineering Analysis |
| Co-PIs: | | | |
| Students: | LCDR Daniel DeCicco (SEA 25 cohort), LTs Alvarez, Arnett, Hook, Thompson, Weeks, Yee (SEA 25 cohort) | | |

Determination Criteria

| | | | |
|----|---|-------------------------------------|-------------------------------------|
| 1. | Is the activity research? For the activity to be research both (a) and (b) must be answered in the affirmative. | YES | NO |
| | (a) Is the activity a systematic investigation? | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| | (b) Is the activity designed to develop or contribute to generalizable knowledge? | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| 2. | Does the activity involve the use of human subjects? For the activity to involve human subjects (a) and (b) or (c) must be answered in the affirmative. | YES | NO |
| | (a) Is the activity designed to collect information about a living individual? | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| | (b) Does the activity involve interaction with a person or persons? | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| | (c) Does the activity involve collecting information that is both private and personally identifiable? | <input type="checkbox"/> | <input checked="" type="checkbox"/> |

Questions as presented are to SMEs about organizational SOPs, technologies, security considerations, and scoping of the capstone project.
PI is advised to ensure that further questions that may arise do not elicit individuals' opinions as they are not covered in this determination. IF these "about who" questions emerge, a new determination and/or protocol application will be required.

| | | |
|---|--------------------------|-------------------------------------|
| IRB Determination | YES | NO |
| The attached activity involves human subjects and requires IRB review and NPS President Approval. | <input type="checkbox"/> | <input checked="" type="checkbox"/> |

IRB Chair/Vice Chair
Signature

SCIARINILLEE.WILLIAM.1
186687260

Digitally signed by SCIARINILLEE.WILLIAM.1
DN: cn=SCIARINILLEE.WILLIAM.1, o=NPS, ou=USC, email=SCIARINILLEE.WILLIAM.1@nps.mil, c=US

Date:

16 SEPT 2016

Naval Postgraduate School
Institutional Review Board
Human Subject Determination Request Form

A determination form may be submitted to the IRB when a researcher is unclear if a proposed activity requires IRB review and approval.

To receive an official determination from the IRB submit the following documents to the IRB Administrator, Rikki Nguyen, ranguyen@nps.edu at least two weeks prior to the estimated research start date.

1. This form completed and signed by the principal investigator.
2. A copy of the approved research proposal.
3. A copy of any data collection tools that may be used in the research (e.g. survey, questionnaire, interview questions)

The IRB will consider the attached documents and if additional information is required to complete the review, the principal investigator will be contacted.

| | |
|--|--|
| A. Research Basics | |
| Title of the Research: | Developing warfighting training to leverage web fires concepts and technologies |
| Department: | System Engineering Analysis |
| Principal Investigator: | Prof. Fotis Papoulas, Faculty Advisor |
| Co-Investigator(s): | LCDR Daniel DeCicco (SEA 25 cohort), LTs Alvarez, Arnett, Hook, Thompson, Weeks, Yee (SEA 25 cohort) |
| Student-Researchers: | TDSI students (SE 13 cohort) |
| B. Data Collection | |
| 1. Will the activity include analysis of pre-collected data? | |
| <input checked="" type="checkbox"/> No <input type="checkbox"/> Yes, Below describe the nature of the data (including data variables) and whether the data will contain personally identifiable information (PII) or personal health information (PHI). | |
| 2. Will your activity include interaction with people? | |
| <input type="checkbox"/> No <input checked="" type="checkbox"/> Yes, Below describe what tasks participant(s) will be asked to perform. | |
| Stakeholder investigation (who) and analysis and requirements (what) for developing warfighting training to leverage web fires concepts and technologies. | |
| Signature: | PAPOULAS.FOTIS.A.123 0510071 <small>Digitally signed by PAPOULAS.FOTIS.A.123 on 08/11/2016 10:05:00-0500, email=USMIL-PAPOULAS.FOTIS.A.123@NPS.NG.MIL, cn=USMIL-PAPOULAS.FOTIS.A.123</small> |
| Date: | |

B. MODIFIED SEA-25 CAPSTONE PROJECT QUESTIONS

Training and High-velocity Learning

1. What technologies are used to train? (VR? Simulators? Classrooms? Online?)
2. Are the scenarios preset? Is Computer Artificial Learning used at all? Are Human (Blue) vs. Human (Red) simulator scenarios used at all?
3. What is the process for modifying simulator scenarios?
4. How are the most up-to-date enemy's tactics and capabilities integrated into current training?
5. How do the instructors interact with the simulators?
6. How is training performed with the simulators?
7. How is doctrine and procedure taught?

Multi-Domain Training Architecture

1. What documented challenges are experienced regarding cross-domain training?
2. How are other communities (such as SWOs/IAMD WTI) integrated into the training?
3. How does _____ (Company/Command) integrate with other training facilities and other communities across the Navy?

Feedback and Future Improvements

1. How is training curriculum feedback reported and implemented?
2. How is simulator HW/SW feedback reported and implemented?
3. How is feedback used to update training, doctrine, and procedures?
4. How is feedback incorporated in updating the warfighting systems and training systems?
5. What improvements are planned for the next generation training facility or architecture?

Current Capabilities

1. What is the current _____ (Company/Command) training pipeline/architecture?
2. What improvements are planned for the next generation _____ (Company/Command) training facility or architecture?

Requirements

1. What training requirements are directed to _____ (Company/Command) from above?
2. What pre-requisites are required for training at _____ (Company/Command)?
3. What pre-requisites or requirements are there to initiate integrated training?
4. What are documented requirement gaps?

Evaluation

1. What are the documented training objectives for units/students?
2. How is the units'/students' performance evaluated?

Training Logistics

1. How many hours a day do students spend in the current system?
2. What is the current system throughput/capacity?
3. What does the current system cost to build/purchase? To operate?
4. How are simulators integrated with other simulators?

NPS IRB
HSR Determination Checklist
last updated: 2-28-17

Instructions: This form is to be completed by the IRB Chair or Vice-Chair when providing an official IRB determination on whether a proposed activity meets the federal definition of research with human subjects according to 32 CFR 219. After completing the form provide to the IRB Administrator. The IRB Administrator will notify the investigators and file electronically.

Title of the Activity: Developing warfighting training to leverage web fires concepts and technologies

Department: Sys Eng Analysis

Principal Investigator: Fotis Papoulias

Co-Investigators: _____

Student Researchers: LCDR Daniel DeCicco (SEA 25 cohort), LTs Alvarez, Amett, Hook, Thompson, Weeks, Yoo (SEA 25 cohort)

Determination Criteria

1. Is the activity research? For the activity to be research both (a) and (b) must be answered in the affirmative. Yes No

(a) Is the activity a systematic investigation? ☒ ☐

(b) Is the activity designed to develop or contribute to generalizable knowledge? ☒ ☐

2. Does the activity involve the use of human subjects? For the activity to involve human subjects (a) and (b) or (c) must be answered in the affirmative. Yes No

(a) Is the activity designed to collect information about a living individual? ☐ ☒

All questions to be asked by the investigators are "about what" (e.g., "What is the process for modifying simulator scenarios?"; "How are the most up-to-date enemy's tactics and capabilities integrated into current training?"; "How is training curriculum feedback reported and implemented?") rather than "about whom." Therefore, this activity is deemed not human subject research.

(b) Does the activity involve interaction with a person or persons? ☒ ☐

(c) Does the activity involve the use of pre-collected information that is both private and personally identifiable? ☐ ☒

IRB Determination

The attached activity involves human subjects and requires IRB review and NPS President approval.

Yes No

☐ ☒

IRB Chair/Vice Chair:

SHATTUCK.LAWRENCE
.GEORGE.1015756825

Digital Signature by
SHATTUCK.LAWRENCE.GEORGE.1015756825
DN: cn=US, o=US, c=Government, ou=DoD, ou=PEL, ou=IRB,
ou=SHATTUCK.LAWRENCE.GEORGE.1015756825
Date: 2017.03.24 11:40:47 -0700

Date:

24 Mar 2017

NPS Institutional Review Board
Human Subject Research Determination Request

Purpose:

To request the IRB review proposed activity and determine if it involves human subject research.

Form Instructions:

To receive an official determination, submit the following to IRB@nps.edu.

1. Determination request form signed by the Principal Investigator (PI). *Note: The PI for student research is the advisor.*
2. A copy of the research proposal or statement of work.
3. Attach any data collection tools (i.e. interview or survey questions, etc).
4. Submit signed determination form and corresponding documents to IRB@nps.edu. An IRB administrator will contact you if additional information is needed.

For questions regarding this form or process send an e-mail to IRB@nps.edu.

Form Updated 2-27-17

A. Research Basics

Title of the Activity: Developing warfighting training to leverage web fires concepts and technologies

Department: Sys Eng Analysis (Curric 3)

Principal Investigator: Dr. Fotis Papoulias

Co-Investigators: _____

Student Researchers: LCDR Daniel DeCicco (SEA 25 cohort), LTs Alvarez, Amett, Hook, Thompson, Weeks, Yee (SEA 25 cohort)

B. Data Collection

1. Will the activity include the use of pre-collected data? Pre-collected data are data that already exist such as fitness reports, personnel records, training records, after action reports, social media data, information from data repositories, existing survey data, etc.

☒ No

☐ Yes, state the following below:

- Describe the data (is it training records, fitness reports, data on all active duty by speciality, data from an old survey, etc).
- State the approximate number of records you will access.
- List the data variables to which you will have access. Make sure to include any PII or demographics contained in the data.

2. Will the activity involve interaction with people?

☐ No

☒ Yes, describe what tasks subjects will be asked to perform (take a survey, be interviewed, participate in a simulation, play a game etc.) and what information subjects will be asked to provide.

Site Visits to Fallon, NV and San Diego, CA. Demonstration of current technologies by SMEs. Interview questions as attached.

3. If a proposal or statement of work is not available, describe the purpose of the data collection and how the data will be used.

OPNAV N96 Tasking statement attached.

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